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THE DEVELOPMENT OF THE CENTRAL CYLINDER OF ARACEAE AND LILIACEAE.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXII.

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(WITH PLATES XII–XV)

THE fundamental unity of the vascular structures found in the higher plants was perceived by VANTIEGHEM, whose conception of the stele and its modifications, outlined in 1886 (**17**), displaced the earlier view of DEBARY. But it became apparent subsequently that VANTIEGHEM'S assumptions were not sufficiently supported by observation. For example, it was shown by GWYNNE-VAUGHAN (**3**) that polystely does not arise by bifurcation of the protostele in the genus Primula, and JEFFREY (**6**) proved the same for *Pteris aquilina*. VANTIEGHEM'S theory is also open to the objection that it is founded on the conditions occurring in a highly organized group of plants, while there would seem to be a better prospect of finding a primitive condition of the vascular system among pteridophytes. In 1897 JEFFREY (**5**) proposed a stelar theory in which this objection is met, the essential feature of which is the important influence on the central cylinder of the outgoing leaf or branch traces. Emphasis is also placed on the study of the young vascular axis, on account of its recognized importance in accordance with the principle of recapitulation. The following diagrams may serve to show the main differences between the two theories:

I. VANTIEGHEM.

1. Protostele

2. Medullated monostele → 3. Astele (schizostele)

4. Polystele → 5. Gamostele

II. JEFFREY (USING THE SAME NUMBERS TO DESIGNATE EQUIVALENT TYPES).

(1) Protostele

(5 and 4) Siphonostele with internal phloem and endodermis (amphiphloic siphonostele)

(3) Siphonostele with internal endodermis (ectophloic siphonostele)

(2) Siphonostele without internal phloem or endodermis.

It will be noticed that JEFFREY derives the vascular structures characteristic of the seed plants from those of the pteridophytes by a process of reduction; further, he considers the pith to be simply fundamental tissue which has intruded through the foliar or ramular gaps, while VANTIEGHEM assumes a stelar origin for the pith.

The researches of JEFFREY (**7**) and GWYNNE-VAUGHAN (**4**) seem to place beyond question the view that the ferns possess an amphiphloic siphonostele derived from a protostelic condition by the bending in of phloem, endodermis, and cortex above the point of exit[1] of the foliar traces; but that the seed plants have primitively a central cylinder built on this plan is a generalization which must be tested by the examination of representatives from a number of typical families in different regions of this great group. With this object in view I have undertaken, at the suggestion of Dr. Jeffrey, to investigate the development of the central cylinder in two characteristic monocotyledonous families, the Araceae and the Liliaceae. Such an investigation ought to answer the following questions:

1. What bearing on current stelar theories has the development of the central cylinder in these families?

2. Are the amphivasal bundles found in so many monocotyledons to be considered a primitive type?

[1] For the sake of clearness the leaf traces will be treated as if they originated at the central cylinder, regardless of the actual direction of their development, which in most cases has not been made out.

3. Does the structure of the young stele throw any light on the question of the origin of the monocotyledons?

ARACEAE.

The number of forms which have been available in this inquiry has not been large, but they are sufficiently varied in their affinities, and appear to the writer to yield no uncertain result.

Pothoideae. This subfamily is regarded by ENGLER (1) as the most primitive one in the family. Hence one of its most available representatives will be first described.

ACORUS CALAMUS.[2]—In a seedling of this plant the central cylinder in its lowest region is a solid mass of vascular tissue, consisting of a core of xylem and a ring of phloem, surrounded by pericycle and endodermis, that is, it is a typical protostele. One trace is given off to the cotyledon, and usually three traces to each of the next three or four leaves, after which the number of foliar traces is increased. In the region where the traces of the second leaf are given off, the central cylinder is seen to possess a parenchymatous pith, which is continuous with the pericycle through the gaps in the vascular tissues caused by the bending out of the traces (*fig.* 1, which, however, represents a higher region of the stem). The endodermis does not bend inward through the gap with the pericycle, but remains unbroken, a portion of it surrounding the trace as it passes outward. Followed downward through the stele the pith either becomes narrower and disappears above the point of exit of the cotyledonary trace, or in some cases enlarges at this point and communicates with the pericycle at the higher node; followed upward the pith widens out with the enlarging central cylinder. As the three traces of the third leaf bend outward, the pith again communicates with the pericycle; since the median trace is the largest of the three, the gap it leaves in the vascular ring is the widest; in fact, the gap of one or both of the lateral traces may be filled only by a single row of parenchymatous cells or may not be present. Up to this point the vascular ring is practically continuous, owing to the foliar gaps being so short, but in the higher regions of the young stem the gaps remain open longer, so that the central cylinder appears to be made up of a ring of sepa-

[2] The nomenclature employed in this paper is that of Engler and Prantl.

rated bundles which are at first collateral, but soon become amphivasal. *Fig. 1* shows this region of the stele. Not until a considerably older stage is reached do certain bundles turn inward and run for a distance in the medulla before turning out to the leaves. *Fig. 2* shows part of a section through the mature rhizome; most of the bundles are amphivasal, and some of them run in the medulla; *g* is a gap through which a medullary bundle has lately passed, and it will be noticed that the endodermis curves inward around the edges of the gap for a short distance, thus making the cortical parenchyma continuous with that of the medulla. This intercommunication of cortex with medulla is even better marked in the base of the flowering axis, as is shown in *fig. 3*. It will be seen that the endodermis extends around the edges of the gaps for a short distance, and completely encircles one small section of the vascular ring. It seems reasonable to believe that if the gaps in the central cylinder of the seedling of Acorus were not so narrow the cortex might communicate with the pith as it does in the seedlings of other Araceae possessing a wider central cylinder.

ANTHURIUM ACAULE.—In the hypocotyl the central cylinder is a hollow tube consisting of xylem, phloem, pith, and surrounded by an endodermis. Just below exit of the single cotyledonary trace the vascular ring breaks up into a circular row of five or six collateral bundles or meristeles. Above the exit of the cotyledonary trace the row is horseshoe-shaped, but soon becomes circular again owing to the reunion of the bundles on the two sides of the cotyledonary gap. The endodermis cannot be followed clearly owing to its poor development. The stele retains its form of a ring of about six collateral bundles through the first internode. At the upper end of the internode several bundles divide, and certain of these turn outward as traces of the second leaf, while others turn inward and run upward through the pith, becoming traces of leaves higher up. In the young stem no concentric strands have been found.

Monsteroideae.—MONSTERA DELICIOSA.—The hypocotyledonary stele consists of a circle of collateral bundles inclosing a parenchymatous medulla. Nearly a third of these bundles bend outward at one side to supply the cotyledon; a little above this point bundles begin to run in the medulla; in other words, the central cylinder early

assumes the characters seen in the adult stem. The bundles are collateral in all parts of the stem. No endodermis can be distinguished.

Calloideae.—SYMPLOCARPUS FOETIDUS has already received some attention in JEFFREY'S preliminary studies of monocotyledons (**6**). The seedling at the age of one year consists of a spherical tuber about 1^{cm} in diameter; from the upper side of this rises a conical bud with a cylindrical base 4^{mm} in diameter, from which spring several roots. A transverse section through the basal region of the tuber shows an elliptical row of collateral strands, each surrounded by an endodermis (*fig. 4*). A little higher up several bundles at one side of the ellipse turn outward, so that at about the middle region of the tuber the bundles are arranged as a horseshoe. Opposite the open part of the horseshoe there is frequently a swelling of the tuber, and in some cases this part of the tuber separates off at a slightly higher level by an abscis layer; this part accordingly constitutes the cotyledon, and the opening in the central cylinder is the cotyledonary gap. Toward the upper part of the tuber the separate strands approach one another, as is shown in *fig. 5*.[3] At *g* is the cotyledonary gap; most of the vascular strands have fused laterally, producing a hollow vascular cylinder with an external and internal phloeoterma (using the term in STRASBURGER'S sense (**15**, p. 310)), broken by the wide cotyledonary gap and by several areas where the individual bundles have not yet fused; through these openings the external and internal phloeotermas are obviously continuous. The latter may persist for some distance upward, finally becoming indistinguishable, or may degenerate quite early, and, as is seen in *fig. 7*, the external phloeoterma runs for a short distance around the edges of the cotyledonary gap, and then disappears. Compare *figs. 2* and *3* of Acorus, also JEFFREY'S figure of *Ranunculus rhomboideus* (**6**, *fig. 16*). A little higher up the cotyledonary gap closes and the stele forms a hollow tube with external and internal phloeoterma. Almost immediately, however, the vascular tissue aggregates into separate strands, the xylem of which is disposed circularly (amphivasal bundles), and a few of these turn into the central region of the stele (*fig. 6*). Each of these bundles is surrounded by a portion of the internal phloeoterma, if this has not

[3] *Figs. 5, 6, 7, 8,* and *11* are from sections treated with sulfuric acid.

already become invisible in this region of the stem, as is seen to be the case in the stem represented in *fig. 8*. These bundles soon become quite numerous and run upward for some distance before resuming their collateral structure and passing outward to the leaves.

Two points of interest in this plant are the existence of a well-marked internal as well as external phloeoterma in the young stem, and the early disappearance of the internal phloeotermal layer. It can hardly be doubted that the thin-walled tissue forming the pith of the stele is simply extrastelar tissue which enters at the base of the stelar system, and through the cotyledonary gap. Absence of the protostelic condition is probably to be accounted for by the shape of the stem; it is in the region of the cotyledonary gap that the central cylinder shows its most primitive condition, namely a vascular tube possessing both external and internal phloeoterma. The spaces between the vascular segments in the basal region of the stem are not foliar gaps, as JEFFREY'S account seems to imply (**6**, p. 29), for this region of the stem is the hypocotyl, and further there are no outgoing bundles between the segments referred to. Separation of the segments may be due to expansion of the young stem as it assumes its tuberous shape.

CALLA PALUSTRIS has been sufficiently described by JEFFREY (**6**). The development of its stele follows pretty closely the course outlined for Acorus, though the endodermis does not seem to be well developed in Calla, also the foliar gaps extend for a greater distance than is the case in Acorus.

Philodendroideae.—SCHIZMATOGLOTTIS ROEBELINII seems to show a scattered disposition of the vascular strands in all parts of its seedling. The material available has not permitted a satisfactory study.

PELTANDRA VIRGINICA.—The seedling possesses a tuberous base consisting of a somewhat cylindrical axial portion with a thick cotyledon applied to its side; the cotyledon is separated in its upper part from the axial portion by a prominent abscis layer. In *fig. 9*, *c* represents the cotyledon, and *r*, *r* secondary roots. A section through the basal part of the tuber shows about eight collateral bundles arranged in a circle (*fig. 10*). Most of these bundles are given off to the cotyledon, so that only a few slender strands continue the

upward course; toward the upper part of the tuber these enlarge and each is seen to be provided with an endodermis whose cells show a cutinized band girdling the radial walls. The strands now unite laterally into a flattened arch whose hollow is turned toward the cotyledon; by continued increase in the vascular tissue the arch becomes more and more nearly a complete circle. In *fig. 11* the cotyledon lies to the right; the individual sheaths have fused to form a common endodermis which is continuous outside and inside the arch; *r* is the trace of a root, which as usual leaves no gap in the central cylinder. *Fig. 12* shows the central cylinder at a slightly higher level; the opening to the right faces the cotyledon, and is undoubtedly the cotyledonary gap. Soon this closes entirely, and at this level the vascular tissue of the stele becomes partly broken up into separate strands, some of which turn into the medulla; each strand and segment of the stele possesses its own endodermis. Amphivasal bundles are found at this level and in the later formed regions of the stem, but they are not so characteristic of Peltandra as of Symplocarpus, to which plant Peltandra evidently possesses many resemblances with respect to its central cylinder. The medullary strands are connected with the traces of all leaves above the cotyledon, and each trace leaves the central cylinder through a gap, around the edges of which the external and internal endodermis are continuous. Eventually, however, the endodermis becomes obsolete, and an increase in the number of medullary strands gives the stele the appearance characteristic of monocotyledons generally. It should be mentioned that the ring of bundles is not always present in the lower part of the tuber; in such cases bundles are so poorly developed in this region that a central cylinder cannot be said to exist below the cotyledonary gap.

ZANTEDESCHIA AETHIOPICA (the ordinary calla lily) and Z. ALBOMACULATA may be described together, since the seedlings are very similar. As the stele of the root merges into that of the hypocotyl it assumes a pith into which several strands turn from the original vascular ring, and soon the whole stele is converted into a network of anastomosing strands. From this network about six bundles are given off to the cotyledon, whose base forms a sheath around the younger leaves. In the succeeding regions of the stem the bundles

pursue the course ordinarily seen in a monocotyledonous stem. In no part of the stem is an endodermis well developed.

Colocasioideae.—ALOCASIA ODORATA.—Above the point of exit of the cotyledonary traces the stele is represented only by a scanty vascular mass of flattened form, its side being turned toward the cotyledon. Further upward this mass splits into several strands, and a ring-shaped row of bundles is completed by the appearance *de novo* of several delicate strands between those already present and the cotyledon. The flattened vascular mass referred to seems to represent the same condition as that shown for Peltandra in *fig. 11*, namely, there is an unusually wide cotyledonary gap, which is not closed in the ordinary way owing to the tendency throughout the plant for the vascular strands to lie widely separated. In a slightly higher region of the stem several bundles come to lie in the medulla and some of the bundles assume the amphivasal shape. No endodermis was found in any part of the stem.

CALADIUM BULBOSUM.—Departure of the cotyledonary trace causes no break in the narrow stele of the seedling; the stele soon becomes complicated by medullary strands which anastomose with one another. In many sections, however, it may be seen that the cortex communicates freely with the medulla above the point of exit of a leaf trace. No endodermis has been demonstrated.

Aroideae.—ARUM ITALICUM.—The five traces which pass into the sheathing base of the cotyledon arise from a complex vascular mass, and the succeeding traces run for a short distance in the medulla. The peculiar habits of sprouting described for another member of the genus by RIMBACH (**10**) and SCOTT and SARGANT (**13**) have probably had the effect of modifying the vascular system; and no part of the plant suggests a primitive condition, but on the contrary a highly specialized one.

ARISAEMA TRIPHYLLUM.—The method of sprouting is essentially like that of Arum. The five cotyledonary traces rise from a vascular mass whose elements anastomose in a complex manner. Above this region the bundles pursue a more nearly vertical course, but are not arranged in a definite central cylinder surrounded by endodermis. In older seedlings the bundles form an extensive network in the central region of the corm. It is probable that the phylogenetic

development of this corm has been accompanied by considerable changes in the vascular system, leading to complications which render this plant unsuitable for the purposes of the present inquiry.

ARISAEMA DRACONTIUM, A. SPECIOSUM, A. INTERMEDIUM, and A. TARTARINOWII all resemble *A. triphyllum* in having seedlings which show a complex network of bundles. They all likewise produce a corm.

TYPHONIUM DIVARICATUM has a vascular system so similar to that found in Arisaema that it does not merit a separate description.

In viewing in a general way the genera so far described the question arises: What characters are to be regarded as primitive? The answer must be, those which occur in the first formed part of the stem, unless there is reason to believe that this region has been influenced by the assumption of some special habit, such as the tuberous or bulbous habit. The stem of Acorus is relatively free from external influences, on account of its geophilous habit; its central cylinder is at first protostelic, then siphonostelic with a pith communicating with the pericycle through the foliar gaps. Judging from the conditions in Symplocarpus and in the mature organs of Acorus, we may infer that if the central cylinder of the Acorus seedling were not so narrow the endodermis and cortex might here also enter through the gaps, in which case the stele would differ from that characteristic of the ferns mainly in the absence of internal phloem, a feature which appears to be quite rare in seed plants. The simple siphonostelic stage persists in Acorus for several internodes, and the stem looks much like that of a dicotyledon; higher up some segments of the stele become amphivasal, and this may be regarded as the first appearance of a monocotyledonous character; very soon certain strands begin to run in the medulla, and so the monocotyledonous nature of the stele is established. The steles of the various genera differ from the type just described in a modification of the basal part of the stele in accordance with the tuberous habit, as in Symplocarpus, or in the rapid disappearance of the phlœoterma, as in Peltandra, or in the early appearance of the medullary strands, as in Arisaema. Whatever may be the nature of the pith in Acorus, there seems to be good reason for believing that in Peltandra and Symplocarpus the pith is

simply fundamental tissue which has been inclosed by the gradual curving around of the edges of the cotyledonary gap until they meet; moreover, the stele is in open communication with the cortex in the basal region of the tuber. It has been shown that in Symplocarpus the internal phloeoterma undergoes a more or less early degeneration, so that the included parenchyma comes to lie next to the xylem, and so might be mistaken for stelar tissue in the upper part of the stem.

It is of interest to note that from a general morphological study of Araceae ENGLER (1) places Acorus among the most primitive genera of the family, and members of the Aroideae, such as Arum and Typhonium, among the most highly developed of the family. My observations on the seedlings accord in the main with ENGLER'S classification; the young stem of Acorus possesses a simple stele, while members of the Aroideae early acquire the most complicated vascular system found in the family.

LILIACEAE.

In this family over fifty species have been studied, representing all the large subfamilies; in most cases both the adult plants and seedlings have been examined. The search for primitive types has convinced me that ancestral characters are most likely to be preserved in a rhizome, since such a stem is free from the modifying influences of an aerial life; hence the first subfamily to be treated is one in which most of the members have the basal portion of the stem a rhizome.

Asparagoideae.—CLINTONIA BOREALIS.—The plant is characterized by a horizontal rhizome which turns upward at the end, bears a number of scales and several foliage leaves, and terminates in a scape carrying an umbel of flowers. *Fig. 13* represents a cross section through the rhizome a short distance before it turns upward; it will be seen that the stele forms a tube perforated at the point of exit of several leaf traces, also that there are no medullary bundles. *Fig. 14* is a more highly magnified view of a portion of the stele. It shows that an internal as well as an external phloeoterma is present, and that these are continuous through the foliar gap; also that some of the meristeles are amphivasal.

CLINTONIA UMBELLATA.—A cross section through the rhizome is shown in *fig. 15;* two foliar gaps with their traces are to be seen, and

here also is an internal as well as an external phlœoterma. Certain of the strands are amphivasal, and three of these have left the stelar ring and run immediately adjacent to it in the medulla. The vascular system of this plant evidently represents a condition slightly more complicated than that present in *C. borealis*. Unfortunately seedlings of neither species of Clintonia have been available, so that the origin of the interesting condition seen in the mature stem remains unknown.

MAIANTHEMUM BIFOLIUM.—The general habit of the plant is similar to that described for Clintonia, though the two foliage leaves arise from a higher region of the aerial shoot. *Fig. 16* represents a section through the rhizome a short distance above where it turns upward. The heavily cutinized external phlœoterma is a prominent feature, and inside of it is a circle of collateral bundles; three amphivasal bundles run in the medulla, but these do not become leaf traces; on the contrary they end as they begin, namely, by joining bundles of the vascular ring. Throughout the horizontal course of the rhizome no medullary bundles are present. Several leaf traces are to be seen at various stages in their escape from the stele; it will be noticed that they cause no break in the continuity of the phlœoterma.

In the seedling the stele contains pith even in the hypocotyl; as the single cotyledonary trace leaves the stele, the phlœoterma bends inward around the edges of the gap, but does not lose its continuity; the pericycle is continuous with the pith through the gap and no amphivasal strands are present. To the second leaf three traces are given off; the median trace causes the phlœoterma to bend inward, as does the cotyledonary trace (*fig. 17*); the lateral traces emerge exactly as in the adult stem (*fig. 16*). The third leaf receives three traces which leave the stele as do those of the second leaf; the same is true of the fourth and fifth leaves. Comparing the stele of this plant with that of *Clintonia borealis*, the absence of internal phlœoterma and the presence of amphivasal medullary strands in the former are to be noted, though these do not make their appearance until a late stage of development.

SMILACINA STELLATA.—As the primary root merges into the hypocotyl, the stele becomes hollow and the vascular tissue aggregates in several collateral strands at the periphery of the stele. An external

phloeoterma is present and is not broken by the exit of a large strand of vascular tissue to the cotyledon. *Fig. 18* shows the appearance of the stele in the first internode, and illustrates the tendency which the stele has to break up into separate strands. The three traces of the second leaf arise in the same manner as the cotyledonary trace; above this level, however, some of the strands become concentric, and one or two branches are given off into the pith, where they run only a short distance, join bundles of the vascular ring, and then pass out to leaves. *Fig. 19* shows such a strand at *m*, and also a leaf trace (*l*) which is just leaving the vascular ring. Higher up other medullary strands run for a greater distance in the pith and turn outward to leaves without anastomosing with bundles of the vascular ring. The seedling of this plant shows clearly the gradual appearance of monocotyledonous characters in a central cylinder which in its first formed part closely resembles that of a dicotyledon. The mature stem both in its subterranean and aerial regions differs from the rhizome of Maianthemum in having a number of medullary strands.

SMILACINA RACEMOSA.—In the youngest plants obtainable the central cylinder exhibited the characters of the adult stem, that is the bundles are scattered through the medulla. Seeds of this plant failed to sprout.

STREPTOPUS ROSEUS.—The stele of the seedling resembles that of *Smilacina stellata* in that it consists of a ring of collateral bundles surrounded by a phloeoterma and enclosing pith; but the bundles early become concentric and afterwards some of them run in the medulla. Bundles of the vascular ring turn outward as leaf traces without destroying the continuity of the phloeoterma.

POLYGONATUM BIFLORUM and P. VERTICILLATUM.—The central cylinder, at first a solid mass, becomes divided into about six widely separated collateral strands at a comparatively young stage; later several medullary bundles appear; a phloeoterma is not distinguishable. The wide separation of the strands is probably due to the fact that the subterranean stem (a horizontal rhizome) early becomes swollen into ovoid form through deposition of starch.

MEDEOLA VIRGINIANA.—The cotyledonary gap is wide; as this closes the stele becomes divided into six or eight meristeles arranged circularly, each provided with its own endodermis and having a

collateral structure. The meristeles unite at the next node and a single strand turns outward, leaving a wide gap in the vascular ring. Again the meristeles separate widely, owing no doubt to the fleshy nature of the stem which by this time has begun to show its habit of a horizontal somewhat swollen rhizome. As the stem turns upward into the air the meristeles approach one another and some of them become amphivasal. At about this point the internal endodermis disappears, but the external layer becomes strongly cutinized. The amphivasal strands resume their collateral structure at a slightly higher level; medullary strands are absent in most plants.

TRILLIUM GRANDIFLORUM.—The subterranean stem is a vertical rhizome which becomes thicker and more ovoidal as the plant grows older, owing to deposition of stores of starch. In the young stem the central cylinder is a solid mass of vascular tissue for a few internodes. The first leaves have three traces; the median trace is much the largest, and as it leaves the central cylinder the latter becomes somewhat crescent-shaped; the lateral traces are very delicate and by their departure leave no indentations in the stele. After exit of the traces of the third or fourth leaf, however, there is intrusion of fundamental tissue into the central cylinder, since the angles of the crescent above referred to curve around and finally close in on the side next the trace. This condition is shown in *fig. 20*; t is the median trace, t_1 is one of the lateral traces whose gap was narrower than that of the median trace and had already closed at this level. The writer fails to see how the thin-walled tissue inside the stele can be regarded as anything but a portion of the fundamental tissue inclosed by approximation of the vascular tissue at the sides of the gap. The appearance above described may be masked by the overlapping of two foliar gaps on opposite sides of the stele; in such a case the stele is broken into two halves (*fig. 21*), a condition which has frequently been described for various ferns. In the upper part of the rhizome the stele becomes complicated by bridges of vascular tissue reaching from one side of the stele to the other; also certain of the leaf traces run for a short distance in the medulla before turning outward. It should be remarked that these medullary strands are amphivasal. In some seedlings the stele retains its solid or protostelic character for many internodes, and it is possible that the diversity noticed in

the various serial sections of seedlings may be due to some of them belonging to *T. erectum* rather than to *T. grandiflorum*, since the seedlings of the two species are hard to distinguish in the field, and I have been unsuccessful in attempts to grow them from seed. In many instances a leaf trace arises from one side rather than from the base of the gap, as has been observed in many ferns, or the trace may run vertically for some distance before turning out from the stelar ring. This condition is shown by the trace marked t_1 in *fig. 22*; t_2 and t_3 are the lateral traces of the same leaf; the last has not quite broken away from the stele.

TRILLIUM SESSILE and T. RECURVATUM greatly resemble *T. grandiflorum* in the seedling stage, but differ from the last species in having wider gaps and showing concentric bundles in a younger part of the stem.

ASPARAGUS OFFICINALIS, A. VERTICILLATUS, A. SPRENGERI, A. VERTICILLATUS, A. BROUSSONETII, and A. MEDEOLOIDES do not appear to throw any light on the problems under consideration on account of the complications attending the formation of lateral buds.

RUSCUS ACULEATUS has a seedling much resembling those found in the genus Asparagus. In the seedlings available the stele had already assumed its mature condition.

Dracaenoideae.—YUCCA FILAMENTOSA.—The hypocotyledonary stele consists of a hollow vascular tube from which about one-third of the vascular tissue turns outward to the cotyledon, leaving a U-shaped stele whose pith is in free communication with the cortex. No phloeoterma was observed. Almost immediately strands turn from the U into the pith, and before the cotyledonary gap is closed these medullary strands are quite numerous. These become traces of higher leaves, so that the stele in this plant quickly attains the characteristic monocotyledonous condition. Nearly all the vascular strands are collateral.

YUCCA ANGUSTIFOLIA and Y. BACCATA resemble *Y. filamentosa* in the young state; in the first-named species the medullary bundles are somewhat later in arising than in the two other species.

DRACAENA DRACO, D. RUBRA, D. VEITCHII, and CORDYLINE AUSTRALIS differ in no essential respect from Yucca as regards the development of the stele.

ASTELIA sp. (*Funkia coerulea*) offers no points of significance.

Lilioideae.—LILIUM CANADENSE.—The young plant consists of a vertical axis upon which is set a spiral series of fleshy awl-shaped scales which are loaded with starch; to each of these three traces run from the tubular central cylinder, taking a course directly outward or even curving downward for a short distance after leaving the central cylinder. These traces, though slender, subtend foliar gaps which frequently extend the whole length of an internode, so that the central cylinder has the appearance of three separate collateral strands, except at the nodes, where a vascular ring is formed, and in the lower part of the seedling, where the scales are more crowded. *Fig. 23* shows the appearance of the central cylinder at a node, *t* is the median trace; bordering the vascular strands are cells differing from the surrounding parenchyma by their entire lack of starch; these may represent a phloeoterma. In the higher regions of the stem the usual medullary bundles appear, and some of these are amphivasal.

ERYTHRONIUM AMERICANUM, CALOCHORTUS VENUSTUS, GALTONIA CANDICANS, SCILLA HYACINTHOIDES, CAMASSIA FRASERI, HYACINTHUS CANDICANS, and LACHENALIA PENDULA early assume the bulbous habit characteristic of the adult plant, hence the stem is flattened in the vertical direction. The complications produced in the vascular tissues by this habit render these genera unprofitable for study, and since there is no reason to believe that the bulbous condition is a primitive one, no description of these genera will be necessary here.

Allioideae.—ALLIUM CEPA, A. CANADENSIS, and A. ANGULOSUM have seedlings much resembling those of the last group in their bulbous habit and intricate vascular system.

AGAPANTHUS UMBELLATUS has a stele much resembling that of Allium.

Asphodeloideae.—ASPHODELUS FISTULOSUS, ASPHODELINE LIBURNICA, BULBINE ANNUA, B. FRUTESCENS, ANTHERICUM LILIAGO, CHLOROPHYTUM ELATUM, KNIPHOFIA TYSONI, K. BREVIFOLIA, and ALOE sp. agree in having short internodes and passing quickly through the early stages of stelar development, so that the medullary bundles are found near the exit of the cotyledonary traces. Further, an endodermis is rarely discernible, so that these genera are unsuitable in the present investigation.

ANEMARRHENA ASPHODELOIDES has been studied with much interest because Miss SARGANT (**11**, **12**) considers that the vascular system of the seedling represents a primitive type. The theory of this author considers chiefly the cotyledonary traces and their insertion; it is natural to inquire whether the stele of the older seedling shows features which may be regarded as primitive. The stele possesses a medulla below the exit of the two cotyledonary traces; these subtend wide gaps through which the cortical and medullary parenchyma freely communicate; the traces of the second leaf are three in number, and before they emerge medullary bundles have made their appearance. Except in the root an endodermis cannot be identified. This fact, and the early appearance of medullary strands, and the presence of a pith in the hypocotyl I do not regard as primitive characters, though it is evident that a plant may retain some ancestral features and lose others, so that the disposition of the cotyledonary strands may still represent an ancestral type.

Melanthoideae.—GLORIOSA SUPERBA.—The peculiar habit of the subterranean portion of the stem has been fully described by QUEVA (**9**), and sufficiently accounts for the complications found in the lower part of its stele; in the upper internodes of the seedling, however, the vascular strands are arranged in a simple ring, and certain of the strands turn outward as leaf traces after anastomosing with adjacent members of the ring.

UVULARIA GRANDIFLORA.—At the point of departure of the cotyledonary trace a wide gap is left in the vascular tissues; here fundamental tissue enters and extends downward into the hypocotyl for a short distance as well as upward. *Fig. 24* shows the stele at level of the cotyledonary gap; the cotyledonary trace is not visible because it bends downward after leaving the stele; though no distinct phlœoterma is visible, the small-celled tissue surrounding the stele certainly does not seem to be continuous across the gap, as it is in some of the adult stems already described. At one place in the stele it will be noticed that the xylem surrounds a mass of phloem, so that the concentric bundles begin to show themselves at this early stage; they make up the whole vascular ring above the point of exit of the second leaf trace; some of them then turn inward and run in the medulla, but here they soon become collateral.

Viewing in a comparative way the genera of Liliaceae described in the foregoing paragraphs, it appears that Trillium exhibits very clearly the stages in development of the stele. These stages may be briefly enumerated as follows: (1) the protostelic condition is present in the basal part of the stem and persists through one or more internodes; then follows (2) the siphonostelic condition in which cortical tissue is included in the stele above the point of exit of the leaf traces and thenceforth forms a medulla; (3) many segments of the stele take on the amphivasal character; (4) strands of vascular tissue, usually amphivasal, turn into the medulla where they run for a greater or less distance and may become connected with leaf traces. Though the stem of Trillium seldom shows any traces of a phloeoterma, *Clintonia borealis* presents a diagrammatic example of a stele which never gets beyond stage (3), and has external and internal phloeoterma which communicate through the foliar gaps. The internal phloeoterma is probably degenerate in Maianthenum except at the edges of the leaf gaps of the young stele; there may be a physiological correlation between the very heavily cutinized external layer and the absence of an internal layer; stage (4) is much delayed in this plant. In *Smilacina stellata* stages (3) and (4) appear sooner; the phloeoterma is less distinct. Medeola and Lilium show the effect of long internodes combined with extended gaps in breaking up the central cylinder into several strands arranged on the circumference of a circle. Uvularia and Streptopus quickly pass into stage (3). Many members of the family such as Allium have assumed the bulbous habit, and in the very short stem of these plants the medullary strands appear very early. They probably express the highest order of specialization shown in the family.

As to the bearing of the foregoing observations on the central cylinder of the two families upon so-called stelar theories, it may at once be stated that though the pteridophytes must be the critical group in any discussion of these theories, yet information from even so highly specialized a group as the monocotyledons is of importance, if we acknowledge the descent of the seed-plants from fern-like ancestors. Many of the Liliaceae studied do not seem to afford any evidence on the points in dispute, which is not to be wondered at when

one considers the adaptations which these plants show; but several plants of both families show characters which, to say the least, are significant.

Concerning VANTIEGHEM'S types, the polystele need not be considered, for no monocotyledon has yet been found with internal phloem; the medullated monostele may be present in such forms as Acorus and Smilacina, but the condi ion may be equally well explained by assuming the degeneration of an internal phloeoterma, deriving this condition from that shown in Clintonia; what may be called an astele or schizostele is probably present in the mature stem of most members of the two families, but in none of the cases examined does t arise by the breaking up of the stele followed by the uniting of the broken ends of the external endodermis on the inner side of the meristeles; on the contrary, wherever the endodermis is discernible in the region of splitting up of the stele, there is an internal as well as external endodermis which communicate at the leaf gaps (*e. g.*, Clintonia); in Symplocarpus each strand which turns into the medulla is surrounded by a portion of the internal endodermis.

Turning to the theory of JEFFREY, a consideration of the figures which accompany this paper shows that there is evidence in the case of the two families studied to support his fundamental statement that the siphonostelic type of central cylinder "is primitively a fibrovascular tube with foliar lacunae opposite the points of exit of the leaf traces" (**6**, p. 38). That the simple tubular condition is found for only a few internodes in most cases is due to the monocotyledons having acquired a new mode of insertion of the leaf traces, which has replaced the mode characteristic of ferns. However, in rhizomes, whose subterranean position has shielded them from the disturbing effects of aerial life,a more primitive type of stele is frequently found; seedlings almost universally show a gap in the central cylinder above the point of exit of the cotyledonary trace, unless indeed they are protostelic at this level, as in Trillium. The siphonostelic nature of the central cylinder is often retained for several internodes, but sooner or later the medullary strands appear, or the gaps persist through an entire internode, in either case resulting in the masking of the essentially tubular nature of the stele. That the young central cylinder of so highly organized a group as the monocotyledons should

show fern-like characters is a fact of considerable phylogenetic significance. The evidence concerning the extrastelar or intrastelar origin of the pith is not so plain, but from the method of closure of the cotyledonary gap in Peltandra and Symplocarpus and of the foliar gaps of Trillium, I am led to believe that the tissue in question has been included; the hypocotyledonary region in Peltandra and Symplocarpus also suggests the unity of extrastelar and intrastelar tissues. Narrowness of the gaps would account for the failure of the endodermis and cortical tissue to enter through the foliar gaps in Acorus, and the absence of internal endodermis in such plants as Maianthemum may be ascribed to degeneration of such a layer as is found in the lower part of the stele in Symplocarpus but disappears in the higher regions of its stele. Thus it appears that the terms "cortex" and "pith" should be used only in a topographical sense, and not as implying a difference of origin, for morphologically they must be regarded as identical, as regions of the "fundamental tissue," using this term in the sense of SACHS and DEBARY. Hence if the term "stele" is used, it should be restricted to the vascular elements of the central cylinder, as is insisted on by FARMER and HILL (**2**). Further, the researches of SCHOUTE (**14**) have shown that HANSTEIN'S dermatogen, periblem, and plerome do not correspond to VANTIEGHEM'S epidermis, cortex, and stele, so that there no longer appears to be any necessity for postulating a common origin for all the tissues found inside the endodermal ring. On the whole, then, the development of the stele in the two families in question appears to support the generalizations made by JEFFREY.

MEDULLARY BUNDLES.—The writer is inclined to believe that these did not originate as leaf traces, but as strands to which leaf traces subsequently became attached. This tentative view rests upon the following considerations:

1. The tendency of the monocotyledonous stele to break up into segments makes it easy for a strand to leave its vertical course at the periphery of the stele and run for a distance in the medulla; such a strand may at a higher level return to its original course, or may join the stelar ring at the opposite side. Both of these conditions are to be seen in the young stele of *Smilacina stellata*. In Maianthemum the first medullary strands to appear do not come in contact with the

leaf traces which arise in this region (*fig. 16*), but higher up return to the stelar ring. It is probable that the anastomosing strands seen in Trillium, Zantedeschia, etc., are of the same nature.

2. VANTIEGHEM (**16**, p. 172) has shown that in *Acorus gramineus* after a bundle has run for a distance in the medulla it divides, one part bending outward as a leaf trace, the other pursuing the medullary course, again dividing further on, and finally passing out to a leaf. The bundle marked *b* in *fig. 2* is in process of division into a medullary bundle and a leaf trace.

3. Medullary bundles are either absent or few in number in rhizomes, but become numerous as soon as the stem turns upward into the air; this is not altogether due to the greater development of leaves in the aerial part.

It is probable that these strands have an important mechanical function, which may explain their paucity in rhizomes; they can hardly have arisen in consequence of a crowding out into the medulla of the too numerous vascular elements of the stelar ring, for they occur in stems whose meristeles do not form a complete ring, *e. g.*, *Smilacina stellata* (*fig. 19*).

AMPHIVASAL BUNDLES. The mode of formation of these was observed by VANTIEGHEM in the mature stem of *Acorus gramineus* (**16**, p. 171); I have traced their formation in the young stele of *Acorus calamus* and *Smilacina stellata*. Starting with a simple collateral bundle of the vascular ring it may be seen that the tracheids increase in number so as to give the xylem a U form and finally an O form. Some strands never go any further than the U stage, and some that have become concentric lose the tracheids of their outer side. It is plain, then, that amphivasal bundles are derived from collateral ones and are simply a modification of the latter type. Since phylogenetic significance has been attached to the concentric and mesarch bundles found in the petioles and peduncles of cycads, it has been thought worth while to find in what parts of the plant in the Araceae and Liliaceae the amphivasal bundles occur. The result of a somewhat extensive investigation of this point may be briefly stated as follows: (1) only collateral strands are found in the lowest part of the stem of the seedling; (2) amphivasal strands are found in the older stem in nearly every genus; (3) the floral axes show only collateral strands,

which may be arranged in a circle or scattered; (4) only collateral strands are found in the leaves. Hence amphivasal strands are to be regarded as cenogenetic structures.

The observations recorded in this paper seem strongly to support the statement made by JEFFREY (**8**) that neither the medullary course of the bundles nor their amphivasal nature are primitive features, but that they appear at a more or less late stage, and that they serve to distinguish monocotyledons from other groups. The plan of the young stele, *e. g.*, Smilacina, bears a close resemblance to that of a dicotyledon, and differs from the older stele of a dicotyledon only in the absence of cambium. The resemblance between the two groups is further shown by the occurrence of medullary strands in several dicotyledonous families, *e. g.*, Nymphaeaceae, and in the older subterranean stem of *Ranunculus acris* (**6**, p. 20); also by the occurrence of amphivasal strands in the mature tissues of such plants as Rheum and Campanula. These considerations lead to the conclusion that the monocotyledons are not an ancient group, but that they have branched off from the dicotyledons, or that both groups have sprung from a parent stock which resembled the modern dicotyledons more closely than it did the monocotyledons.

CONCLUSIONS.

1. The members of the Araceae and Liliaceae have primitively a collateral tubular central cylinder, or ectophloic siphonostele, derived from a protostele, and interrupted by gaps above the points of exit of the foliar traces; through these gaps the external and internal phlocotermas communicate; the intrastelar parenchyma is to be regarded as having the same origin as the cortex, *i. e.*, both cortex and medulla are portions of the fundamental or ground tissue.

2. This primitive condition becomes altered (1) by degeneration of either the internal phlocoterma or both the internal and external phlocotermas; (2) by the assumption of a medullary course by some vascular strands, with which leaf traces are connected; hence the scattered arrangement of bundles is to be regarded as a cenogenetic character.

3. The amphivasal concentric strands are not a palingenetic feature, for they are derived from collateral strands and do not occur in the base of the seedling nor in the leaves and floral axes.

4. Anatomical evidence favors the derivation of monocotyledons from dictoyledonous ancestors.

The subject of this paper was suggested by Dr. E. C. Jeffrey, and the investigation has been carried out under his direction and that of Dr. J. M. Coulter; to both of these gentlemen I wish to tender my best thanks for valuable assistance in the work and in securing material. Thanks are also due Miss E. Sargant, of Reigate, England, for material; to Professor Ikeno, of Tokio, for seeds of Anemarrhena; and to Sir W. T. Thiselton-Dyer, Dr. N. L. Britton, and Dr. W. Trelease for seeds of various species from the botanical gardens under their direction.

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EXPLANATION OF PLATES XII–XV.

PLATE XII.

FIG. 1. *Acorus Calamus;* section through stele at point of exit of traces of third leaf. × 90.

FIG. 2. Same; part of mature stem: *b*, bundle in process of division into leaf trace and medullary bundle; *g*, gap through which a leaf trace has recently passed; *c*, cortex; *m*, medulla. × 55.

FIG. 3. Same; central cylinder from base of flowering axis. × 35.

FIG. 4. *Symplocarpus foetidus*; section through basal region of tuber. × 15.

FIG. 5. Same at region of the cotyledonary gap (*g*). × 25.

FIG. 6. Same a short distance higher up; cotyledonary gap closed. × 25.

PLATE XIII.

FIG. 7. *Symplocarpus foetidus;* specimen showing early degeneration of internal phlocoterma. × 25.

FIG. 8. Same; region above closure of the cotyledonary gap. × 25.

FIG. 9. *Peltandra virginica;* general view showing cotyledon (*c*) partly separated off; *r*, *r*, secondary roots. × 7.5.

FIG. 10. Same; basal region of seedling. × 30.

FIG. 11. Same; region of cotyledonary gap; *r*, secondary root. × 25.

FIG. 12. Same; cotyledonary gap closing. × 25.

PLATE XIV.

FIG. 13. *Clintonia borealis;* stele of mature rhizome. × 25.

FIG. 14. Part of section shown in *fig. 13.* × 85.

FIG. 15. *Clintonia umbellata;* stele of mature rhizome. × 20.

FIG. 16. *Maianthemum bifolium;* stele of mature rhizome shortly above region at which it turns upwards. × 25.

FIG. 17. Same at the second node. × 85.

FIG. 18. *Smilacina stellata;* stele in the second internode. × 125.

PLATE XV.

FIG. 19. *Smilacina stellata;* higher region of seedling; *m*, bundle which has left periphery of stele to run for a distance in the medulla; *t*, leaf trace. × 65.

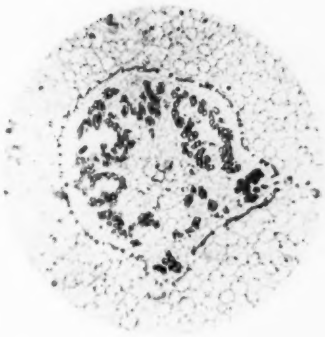
FIG. 20. *Trillium grandiflorum;* young stele: t, median trace of a leaf; t_1, lateral trace of same leaf. × 30.

FIG. 21. Same; stele slightly higher than the preceding, showing two foliar gaps overlapping. × 50.

FIG. 22. Same still higher; t_1, median trace; t_2, t_3, lateral traces. × 50.

FIG. 23. *Lilium canadense;* node of seedling; t, median trace of leaf lying to the right. × 60.

FIG. 24. *Uvularia grandiflora* immediately above point of exit of the cotyledonary trace. × 95.



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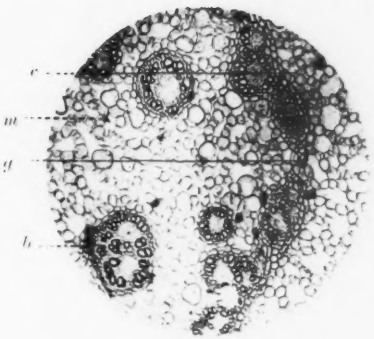

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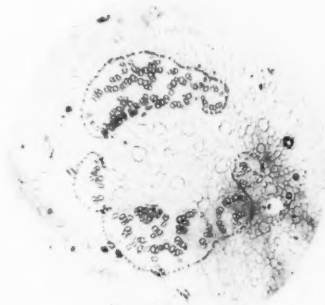

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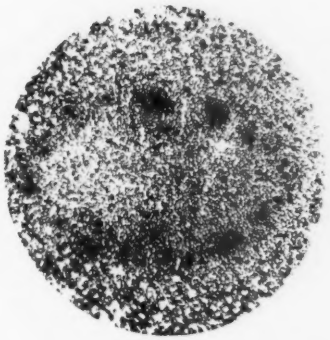

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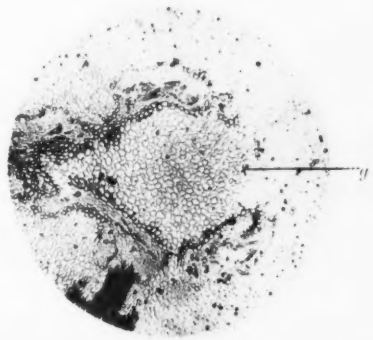

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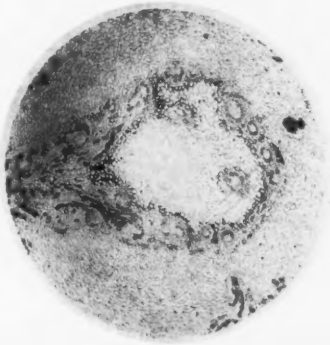

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CHRYSLER on CENTRAL CYLINDER.

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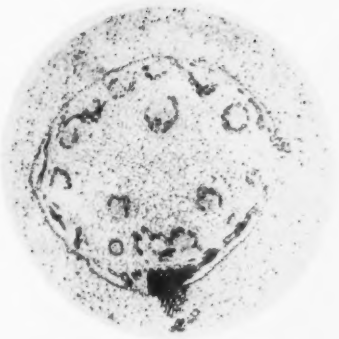

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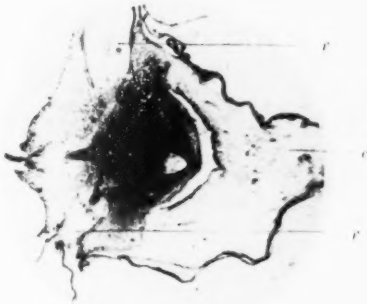

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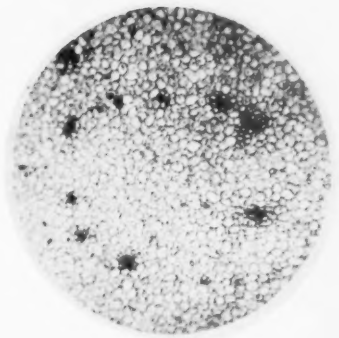

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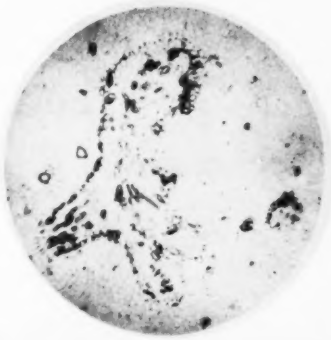

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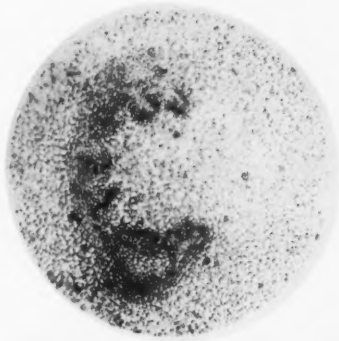

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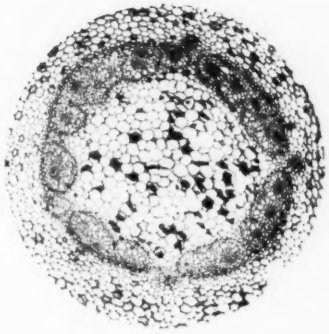

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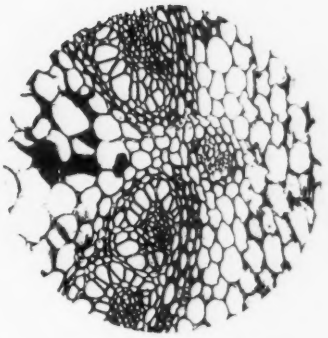

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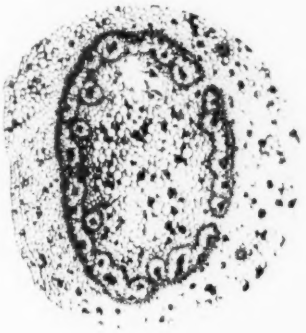

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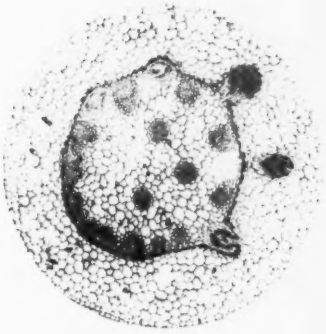

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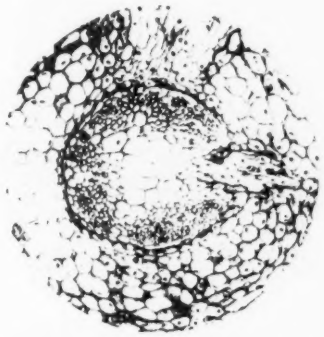

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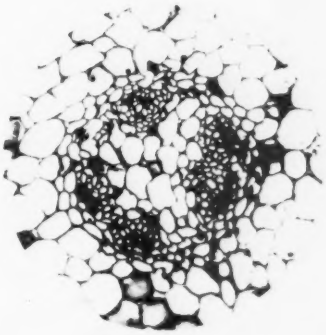

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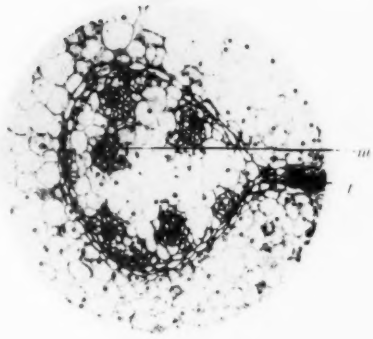

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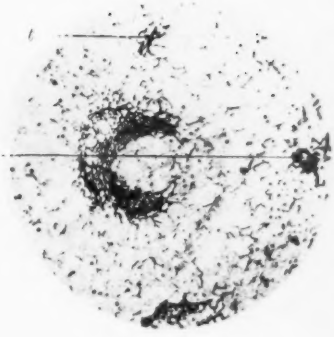

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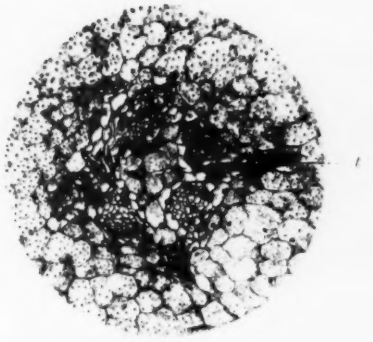

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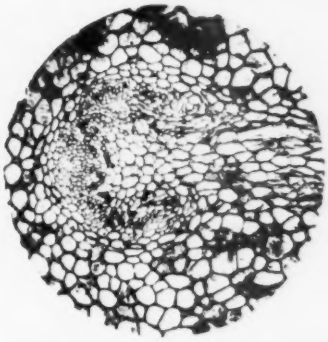

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CHRYSLER on CENTRAL CYLINDER.

THE DEVELOPMENT AND RELATIONSHIP OF MONOCLEA.[1]

CONTRIBUTIONS FROM THE BOTANICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY, No. 2.

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(WITH PLATES XVI AND XVII)

WHILE studying and collecting the native Piperaceae of Jamaica, in the spring of 1903, I also preserved plants in various stages of development of the liverwort *Monoclea Forsteri* Hook. The results of the study of the material of this little known form are given in the following pages.

Monoclea occurs in Jamaica chiefly on wet rocks and banks in the mountain forests (CAMPBELL '98). The most luxuriant growth of it seen by the writer was one of many meters in extent in a small depression near New Haven Gap in the Blue Mountains. This depression was filled up considerably by living and decaying vegetation, but the water in it stood at such a level that the tangles of Monoclea and associated plants were practically floating upon its surface. The appearance of a mat of Monoclea is not so much like one of the more attenuated plants of Marchantia or Fegatella as it is like a mat of gigantic Pellia, though the edges of the thallus are often more crisped or curled upward than in the latter genus. The plants growing in the water at New Haven Gap were often 3^{cm} wide, in the case of the broader branches, while elsewhere they seldom exceeded 2^{cm}. The growing ends of these aquatic plants were almost erect, apparently because of the wet substratum, since this peculiarity did not seem to be attributable to the direction from which light reached them.

A majority of the plants found were sterile, and in the case of the plants growing in wetter situations fertile plants were very scarce. In groups of plants growing in the damp ravines, where the substratum was not so completely saturated with water, though the air was saturated with water vapor, fertile plants of both sexes were easily found.

[1] An investigation pursued with the aid of a grant from the Botanical Society of America.

The older female plants were most readily distinguishable by the presence of the large tubular involucre enclosing the large sporogonia. Male plants were readily found, being slightly smaller than the female plants, but in most of them the antheridia had matured and discharged, and only the shriveled male receptacle remained. Careful sorting of large amounts of material was necessary at the season I was in Jamaica, in order to discover young male receptacles with developing antheridia in them.

HISTORICAL RÉSUMÉ.

Monoclea Forsteri was originally described by HOOKER ('20), from material collected (in "Insulae Australes") by FORSTER while accompanying Captain COOK on his famous voyage. HOOKER was aided also by a drawing and a manuscript description of the plant by FORSTER, who had named it *Anthoceros univalvis*. The general form of the non-costate thallus, the simple involucre, the lack of a female receptacle, and the structure of the open capsule, all features which were shown in HOOKER's *fig. 1.* were apparently taken from FORSTER's drawing. By study of the specimens HOOKER made out that the unopened capsule was cylindrical, and that it opened by a single lateral slit. He also figured the spores and elaters and noted the presence of three well-developed capsules in a single involucre, each with its own tubular calyptra.

The removal of the plant from the genus Anthoceros, and the establishment of the genus Monoclea to receive it, was based by HOOKER on the absence of the columella and the presence of but one valve in the open capsule.

Ten years later HOOKER ('30) described as *Monoclea crispata* a liverwort found in the island of St. Vincent, in which he found a univalve capsule like that of Monoclea, and a columella like that of Anthoceros. This latter led him to think that he had probably overlooked a columella in *M. Forsteri*, and to decide that Monoclea was probably intermediate between Anthoceros and the Jungermanniaceae.

TAYLOR ('44, '45), apparently after consulting HOOKER's later paper only, added two other species to the genus Monoclea.

A year later NEES VON ESENBECK ('46) established the genus Dendroceros to contain HOOKER's *M. crispata* and Taylor's species,

but failed to recognize the full importance of the differences between the involucre, calyptra, and sporogonium of *M. crispata* and those of the other forms included in the genus by HOOKER and TAYLOR, and apparently based the division of the genus chiefly on the columella.

GOTTSCHE ('58) studied material of Monoclea from Chili. From this he described the gross and minute structure of the vegetative thallus, noting the presence of two types of (non-tuberculate) rhizoids and the occurrence of fungus hyphae in certain cells of the thallus. The involucre he thought completely closed at first. He also described the structure of the mature sporogonium, from the foot to the capsule, with its one-layered wall, unicellular elaters, and roughened spores. On the basis of these observations GOTTSCHE clearly distinguishes *M. Forsteri* from the species of Dendroceros with which it had been associated by HOOKER, TAYLOR, and NEES, and seems to find in it close resemblances to Pellia and Blasia, with which he frequently compares it. He also remarks on the outward likeness to Marchantia which had been noted earlier by HOOKER ('20, p. 176).

Nine years later still GOTTSCHE ('67) discovered the elevated, oval male receptacle on plants of Monoclea from Mexico.

The next important worker on the genus was LEITGEB ('77), who confirmed the work of Gottsche on the structure of the thallus, calyptra and capsule, and insisted on the similarity in structure and branching of the thallus with that of Pellia and Symphyogyna, rather than with that of the dichotomous, areolate Marchantiaceae. He described the slender, thick-walled rhizoids, found by GOTTSCHE ('58), as generally distributed over the under side of the thallus, and as lying parallel to it, while the larger, thin-walled ones are, as GOTTSCHE showed, confined to the median portion of the thallus and stand out perpendicular to the latter. LEITGEB found that the involucre arises as a depression in the tip of the thallus, being closely like that of Pellia in origin and structure. He also discovered that the involucre is independent in its development of that of the sporogonium, and even of fertilization. No young archegonia or embryos were found. The mature archegonia occur in groups of eight or ten, have a large venter, and a long twisted neck. The capsule he thinks imperfectly four-valved. From these facts LEITGEB concludes that Monoclea is more closely related to Pellia than to any of the Marchantiaceae.

In 1881 LEITGEB studied alcoholic material of male and female plants of a Monoclea from New Zealand, the male plants of which had earlier been described as *Dumortiera dilatata*, and found that, except in the larger size of the plants and of the involucre, they agreed closely with *Monoclea Forsteri*. In the male plants he found that the form and distribution of the male receptacles was as described by GOTTSCHE ('67). The receptacles he likens to those of Fegatella, and notes that the elongated, conical antheridia are secondarily sunken in the cavities of the receptacle. These characters of the male plant he thinks show as striking a resemblance to the Marchantiaceae as do those of the female plant to the Jungermanniaceae, but which set of characters is to preponderate as an index of relationship LEITGEB does not definitely decide.

SCHIFFNER('93), in characterizing the genus Monoclea, apparently overlooks the later papers of both GOTTSCHE and LEITGEB, and states that the male plant is unknown. He also says that the wall of the capsule is of two layers of cells, though both GOTTSCHE and LEITGEB say it is one-layered. SCHIFFNER is then naturally led to follow LEITGEB'S earlier conclusion ('77) that Monoclea is shown by the female plant and sporogonium to be closely related to Pellia.

Coincidently with SCHIFFNER'S work appeared a paper by RUGE ('93), in which he described the development of the male receptacle and the antheridium, as worked out on preserved material from Venezuela, more completely than had been done by LEITGEB. According to RUGE several transverse walls appear in the primarily superficial antheridium mother-cell before any longitudinal ones are formed. The series of figures given does not show the details of the further development of the antheridium clearly, and the series for the archegonium is still less satisfactory.

In this description of the female plant RUGE agrees with GOTTSCHE and LEITGEB, but gives more details as to the development of the archegonial cavity. RUGE, for some reason not clear to the writer, described the slender rhizoids as being also thin-walled and the larger ones as thick-walled, the exact contrary of the condition found by GOTTSCHE, LEITGEB, and the present writer.

CAMPBELL ('98) in a short paper reviews briefly the bearing of the work of HOOKER, GOTTSCHE, LEITGEB, and RUGE, and points out

that the work of the latter (though RUGE apparently failed to appreciate this) materially adds to the likenesses between Monoclea and the Marchantiaceae, which LEITGEB ('81) had already noted.

From the presence of two types of rhizoids, the development of the male receptacle and the antheridium, and from the structure of the mature archegonium made out by CAMPBELL himself, he concludes that Monoclea is to be included in the Marchantiaceae. The absence of ventral scales and of the air chambers, characteristic of the Marchantiaceae, he thinks cannot be considered a greater objection here than in the case of Dumortiera, in certain species of which he has shown that the air chambers are not present at any stage of development.

THE MALE RECEPTACLE.

The male receptacle of Monoclea is a slightly elevated oval area, 4–10^{mm} long and 2–3^{mm} broad, on the median line of the upper surface of the thallus (*fig. 1*). In general appearance it is something like the male receptacle of Fegatella, but in origin it resembles more closely that of Fimbriaria (CAMPBELL '95), since the receptacle is not sunken into the thallus and is not the product of several growing points, both of which features CAVERS ('04) has shown to be characteristic of Fegatella.

The antheridia of Monoclea occur in groups of fifteen to fifty, arranged in four to six rather indefinite longitudinal rows along the receptacle (*figs. 1, 2, 4, 6*). They arise in acropetal succession, and the antheridia of the same receptacle may range in development from those of a few cells each at the anterior end to nearly ripe antheridia at the posterior end (*figs. 8, 9*).

The male receptacle arises by the upward growth of the cells of the thallus round about and among the antheridia of a group (*figs. 6, 9*). This upward growth of the sterile cells is subsequent to the formation of the antheridium rudiments (*fig. 6*), and thus progresses, like the development of the latter, from behind toward the growing point. When the formation of antheridia ceases for a time, the growing point which has given rise to the antheridia pushes on, forming a stretch of vegetative thallus of normal thickness (*fig. 9*). Thus the receptacle has an abrupt ending in front, with an elevated and slightly overhanging margin, like that on the lateral and posterior edges (*figs. 2, 3, 8, 9*).

Three or four successive series of receptacles may often be seen on the same plant (*figs. 1, 3*). The youngest of these appear as crescentic regions at the growing point, with only the posterior edge slightly elevated above the thallus (*figs. 1, 4*). Whether more than one series of receptacles arise in one year was not made out with certainty, but I am inclined to believe that one series may be formed in each of the two rainy seasons that occur in Jamaica each year. Not infrequently a receptacle is found which extends up each branch from the point of forking of the thallus. This is due to the division of the growing point into two after the formation of antheridia has begun. The series of antheridia from the two growing points are clearly distinguishable in the young receptacle (*fig. 5*).

The older receptacles, after the ripening and discharge of their antheridia, become somewhat shriveled and brown, but finally disappear only with the progressive decay of the plant from the base (*figs. 1, 3*).

THE ANTHERIDIUM.

The mother-cell of the antheridium is first distinguishable when it is but a few cells back from the initial of the thallus, but the exact age or portion of the segment from which it arises was not determined. It is first recognizable because of its greater size and the darker staining of its contents, by its failure to divide by perclinal walls as early as the surrounding cells, and finally by the gradual separation of its lateral walls from those of the surrounding cells (*fig. 6*). This separation of the lateral cell-walls begins at the outer surface, and even before it is completed the surrounding cells begin to push upward more rapidly than the antheridium itself, and soon close in above it to a narrow pore (*figs. 6, 8, 9, 13*). Thus each antheridium finally comes to lie in a long-necked, flask-like cavity in the male receptacle. From the cells lining this cavity, club-shaped unicellular hairs are formed, which probably secrete the abundant slime that completely fills the older cavities around the antheridium and oozes out at the neck of the cavity (*figs. 8, 9, 13*). In paraffin sections this slime, with the imbedded hairs, has the appearance of a shrunken cellular jacket. The similar mass of slime in the archegonial cavity led GOTTSCHE ('58, *fig. 16*) to describe this mass as a structureless membrane, bearing hairs.

Soon after the separation of the antheridium mother-cell from the surrounding cells, it divides transversely into a terminal or body cell and a basal or stalk cell. The latter remains attached to the cells at the bottom of the pit, while the former is free from all but the stalk cell (*figs. 6, 10, 13*). The body cell soon becomes remarkable because of its denser contents and its more active division. It first divides twice transversely, and thus gives rise to four primary cells in the body of the antheridium (*figs. 6, 10*). Meantime the stalk cell of the antheridium divides into two, the upper one of which usually remains undivided for some time, while the lower one soon divides by a transverse wall (*figs. 11, 12, 13*). There are thus usually seven tiers of cells in the antheridium at this stage. Of these the three basal ones are concerned with the formation of the stalk, while the four terminal ones give rise to the body of the antheridium (*figs. 11, 12, 13*).

The stalk is more evident in the younger antheridium, since in the older ones, though it is several cells broad, it is usually crushed down by the rapid elongation of the antheridium, which pushes upward against the roof of the antheridial cavity and downward upon the stalk (*figs. 9, 13*).

The first longitudinal wall in each of the four cells of the body of the antheridium is a diametric one (*fig. 15*). Each of the two cells so formed is then cut by a radial, longitudinal anticline, and thus quadrants are formed (*fig. 16*). The next wall appearing in each quadrant is a pericline, which cuts off an outer wall cell from an inner spermatogenous one (*figs. 11, 13, 17*). Next there appears in each wall cell a radial anticline (*fig. 17*), and this is soon followed by other longitudinal and some transverse anticlines, but no periclines are formed in the wall cells except at the tip of the antheridium. Here the cells of a small group divide by one or two periclines, and thus give rise to the thickened terminal area in the wall of the mature antheridium (*figs. 9, 14*). The rest of the wall of the mature antheridium is one-layered throughout. The cells of the wall at maturity are somewhat elongated longitudinally to the antheridium and are about equally thickened on all sides. The place and mechanism of the opening of the antheridium were not observed.

The primary spermatogenous cell of each quadrant of the antheridium breaks up, at first in a pretty regular manner, by approximately

longitudinal anticlines (*figs. 18, 19, 20*). Then by the appearance of other longitudinal and transverse anticlines a very large number of spermatogenous cells are formed. The nuclear divisions in these spermatogenous cells occur simultaneously over larger or smaller blocks, commonly extending over one-tenth to one-fifth the area of a longitudinal section of the antheridium, but never over the whole of it at once. In several of the antheridia examined there were found to be from 35 to 50 of these cubical spermatogenous cells on a single diameter, and from 125 to 160 of them in the length of the antheridium. This means that there are from 100,000 to 250,000 of these cells in a well-developed antheridium. Each of these cubical cells divides later by a diagonal wall to form two triangular-prismatic spermatozoid mother-cells. There are thus formed from 200,000 to 500,000 spermatozoids in each antheridium.

The organization of the spermatozoid in the mother-cell begins, as in other described liverworts, by the elongation and coiling of the nucleus. The presence of a blepharoplast was not demonstrated. When mature the spermatozoid is coiled to about one and a half turns in a flat spiral, whose axis is perpendicular to the broader side of the triangular-prismatic mother-cell.

The most striking peculiarity shown in the development of the spermatozoid is the fact that the individuality of the chromosomes is visibly persistent in the ripe spermatozoid. Careful study of the mitotic figures in spermatogenous cells at various stages of development showed the number of chromosomes to be eight or ten. In preparations of ripe antheridia, which had been fixed in Flemming's solution and stained in Flemming's triple stain, when washed so as to show well the chromatin in the vegetative nuclei round about, the spermatozoids appeared as single dark blue coils. When however the sections were washed out more completely, so that even the nuclei were of a faint blue, the color remaining in the spermatozoid was confined to a number of fine threads of nearly the length of the spermatozoid. These threads were twisted about each other slightly so that each thread in its length made a complete turn about the nearly cylindrical spermatozoid (*fig. 8a*). A careful count of these threads, which could best be made in optical transverse sections of the coils of the spermatozoid, showed that the number is constant and identical

with that of the chromosomes in the spermatogenous cells (*fig. 8b*). The fact that no other part of the spermatozoid retained the stain, and the constant agreement in number just mentioned, seems to leave no doubt that these threads in the spermatozoid are the greatly elongated chromosomes. The significance of this unique individuality of the chromosomes in the nearly ripe spermatozoid might be discovered by a study of the process of fertilization and the behavior of these chromosomes in the fusion nucleus of the fertilized egg. This I was unable to accomplish because of a lack of material of the particular stage needed.

THE ARCHEGONIUM.

The portion of the thallus from which the archegonia develop is not as much differentiated from the vegetative part as is the male receptacle. The archegonia arise in acropetal succession, in groups of six to ten, on the upper surface of the thallus just back of the growing point. At about the time of origin of the first archegonia of a group, for these differ considerably in age, the thallus begins to thicken just behind the growing point. A longitudinal section of this region at this time would look much like that of a young male receptacle (*figs. 26, 27*). Soon the upper anterior edge of this thickening grows forward to form a hood-like involucre above the archegonia (*fig. 28*). This hood-like roof above the archegonia keeps pace with the advance of the growing point below, and thus is formed the long, tubular involucre, which may become 15^{mm} or more in length, though seldom more than $3–4^{mm}$ in width (*figs. 22, 29, 30, 31*). Though widely open at first the involucre is finally closed anteriorly except for a very narrow slit, the edges of which fit together closely (*figs. 22, 29, 31*). After a growing point has given rise to a single series of archegonia and has done its part in forming the lower side of the involucre its activity ceases. Then a new growing point appears on each side of the involucre at the anterior end (*fig. 22*). By the activity of these a new branch is formed on each side and the involucre is left behind at the juncture of these two branches.

Lining the walls of the involucre on the inner side, among the archegonia, are large numbers of glandular hairs, which are outgrowths of the superficial cells. These are usually cut off by a transverse wall from the parent cell (*figs. 28, 33*). These slime-secreting hairs

seem, like those of the antheridial cavity, constantly more slender in form than the bent, club-shaped hairs which occur close to the growing point, as was noted by RUGE ('95).

The early stages of the archegonium were not made out as completely as were those of the antheridium, but the stages seen were sufficient to show that the archegonia of Monoclea agree essentially in the early stages of their development with those of other liverworts that have been carefully studied. Thus in *fig. 32* we have a young archegonium with wall cells, a cover cell, and three axial cells of which the lower is evidently destined to form the egg and ventral canal cell, while the upper are to break up into neck canal cells. The structure is in other words identical in all respects with that of the young archegonium of all the well-known Marchantiaceae and Jungermanniaceae (*cf.* CAMPBELL '95, *figs. 2, 17, 46*, and GOEBEL '98, *fig. 137*).

The mature archegonium (*fig. 33*) has a rather broad stalk, a well-marked venter, and, as noted by LEITGEB ('77, p. 67) and RUGE ('93), has also a very long neck (*figs. 28, 29, 33*). In the cavity of the archegonium is found a large, oval egg, a small ventral canal cell, and an unusually large number of neck canal cells. The number of the latter is larger than ten, and in the case figured was apparently fourteen, though the cells shown in dotted outline could not be made out clearly, being located just at the level of juncture of the two adjoining sections from which the drawing was made.

The number of cells seen in a transverse section of the neck of the archegonium is usually six, as shown by CAMPBELL ('98), but occasionally five and frequently seven or eight were found (*figs. 35, 34*).

The twisting of the cells of the neck of the archegonium was not nearly so marked in my material as in that studied by LEITGEB ('77) and RUGE ('93).

As noted above, the hood-like involucre begins its development long before the archegonia are mature, hence, as was pointed out by LEITGEB ('77), it cannot be the result of fertilization as GOTTSCHE ('58) believed. The archegonium shown in *fig. 33* was found in the involucre shown in *fig. 28*. Since the archegonium is practically ripe it seems evident that the fertilization of most if not all of the archegonia must take place before the mouth of the involucre is much contracted. The size of many involucres containing embryos points to

the same conclusion. It may still be, however, that the unusually long neck of the archegonium is of advantage in insuring fertilization, as suggested by LEITGEB ('77, p. 65) and RUGE ('93), though the involucre is not so nearly closed at the time of fertilization as they apparently supposed.

The wall of the venter of the archegonium becomes two-layered before fertilization. After fertilization, as the embryo develops, the venter increases greatly in length and in thickness, forming thus a long tubular calyptra which may be twelve or fifteen cells thick near the base (*figs. 31, 39, 41*). This calyptra is ultimately ruptured near the top by the elongation of the seta, in such a manner usually as to leave it more or less two-lipped.

THE SPOROGONIUM.

The actual fertilization of the egg was not observed. At some time after the maturation of the archegonium, the neck shrivels at the tip, the wall of the venter begins to thicken; the egg then increases in size and cell divisions appear in it (*fig. 38*).

Material was not available for the determination of the sequence of the earliest divisions of the embryo, and from the youngest ones seen it could not be discovered whether these were longitudinal or transverse. That longitudinal walls appear very early is evident from *fig. 36*, and the transverse wall near the middle in this figure may be the primary one of the embryo, as is usual with other liverworts. That there is a quadrant formation in the upper part of the embryo is evident from *figs. 41, 42*.

The differentiation of foot and capsule appears early in the development and is indicated by the more rapid enlargement in diameter of the former and by the larger cells of which it is composed (*figs. 31, 38, 39, 40*). The capsule later increases in diameter so as slightly to exceed the foot, and becomes elongated to eight or ten times its diameter (*fig. 31*). The seta is developed from just above the constricted region that first marks the separation of foot and capsule (*figs. 31, 38, 40*). Later on this constriction is obliterated, the foot and seta differ little in diameter (*fig. 31*), and the foot is not as sharply distinguished from the rest of the sporogonium as is shown by GOTTSCHE ('59, *fig. 17*).

The longitudinal walls which immediately follow the quadrant-walls in the capsule do not appear in very regular order, but there is soon discoverable an inner series of six or eight cells surrounded by an outer layer of about twice as many cells (*figs. 37, 41, 42*). The latter series form the wall of the capsule, while the former give rise to the spores and elaters (*figs. 40, 43, 44, 45*). Apparently no further periclines are formed in these primary wall cells, except at the top of the capsule (*figs. 31, 45, 48*). Thus all but this portion of the wall is a single layer of cells as described by GOTTSCHE ('58). I have seen no authority for the statement by SCHIFFNER ('93) that the wall is two-layered.

These cells of the wall of the capsule, as has been carefully described by GOTTSCHE ('58), have their walls provided with an elaborate series of thickening bands. The cells of the basal part of the wall are elongated to five to ten times their width, while those at the top of the capsule are nearly equal in length and in tangential width, though somewhat irregular in shape. The rupture of the ripe capsule originates at the top and extends down one side to allow the smooth-edged flaps to open out to the spoon-like form figured by HOOKER ('20). The mature capsule is about 1.5 mm in diameter and 6–8 mm long.

The seta of the nearly ripe capsule is about 1 mm long and in the final stretching to elevate the capsule increases to 30–40 mm. Before stretching, the sporogonium has a nearly horizontal position in the involucre, but as the seta extends it curves upward and the capsule finally becomes vertical in position.

Just before elongation the component cells of the seta are 30–35 μ wide and 12–16 μ long. During elongation the width of the cells changes but little, while the length increases often to 0.5 mm.

The division of the archesporial cells in the interior of the capsule goes on without evident differentiation until there are about 30 or 40 cells on a diameter of the capsule (*figs. 43, 44*). Soon after this the cells elongate markedly in a direction longitudinal to the capsule (*fig. 45*.) When their length has reached five to ten times their diameter (*fig. 46*), some of the thicker cells divide transversely and each gives rise to eight cubical spore mother-cells. Other more slender cells continue to elongate greatly to form the elaters (*fig. 47*). The elater-

forming cells are thus not sister cells of the spore mother-cells, but rather of cells which give rise to several of the latter. The longitudinal grouping of the spore mother-cells in *figs. 47* and *49* indicates their origin, and the pointed, terminal mother-cell of each row in *fig. 47* recalls the spindle-like form of the parent cell.

When the capsule is about three quarters grown, that is when it is 3 or 4^{mm} long, the spore mother-cells round off from one another. Soon afterward they assume the usual four-lobed form (*fig. 49*). Then follows the division of the nucleus and the separation of the spores of the tetrad in the usual manner. The mature spores are uninucleate, nearly globular, 16 to 18μ in diameter, and have a thick, reticulated wall (*figs. 51, 52*).

The elaters continue to elongate as the spores are maturing and ultimately reach a length of 150μ. They are about 8μ in diameter in the middle, and taper to a rather blunt end in each direction. Some time after the individual spores are formed two rather closely twisted, spiral, thickening bands appear in each of the elaters (*fig. 50*). These bands are about as wide as the interspaces of thinner wall left between them. One of the bands often disappears considerably before the other as the end of the elater is approached. No grouping of the elaters or attachment to the wall of the capsule was noticed, except the attachment of a few scattered elaters at the base of the capsule to the wall near the end of the seta.

The elongation of the seta occurs after the capsule is practically ripe, and the latter opens soon after being pushed out of the involucre. The opening seems to proceed gradually, and the escape of the spores, aided by the twisting and untwisting of the elaters, is thus distributed over a considerable portion of time.

CONCLUSIONS.

HOOKER ('20), GOTTSCHE ('58), and LEITGEB ('77, p. 62, and '81, p. 132) all recognized the similarity of Monoclea in size and habit to the Marchantiaceae, and LEITGEB noticed the likeness in the structure of the antheridium and the male receptacle to those of the same group of liverworts. But the form of the involucre, the structure of the archegonium, and especially the absence of air chambers and (as they believed) of tuberculate rhizoids, led all these workers to keep Monoclea out of the Marchantiaceae.

GOEBEL ('98, p. 240) points out the similarity in the development of the antheridium of Monoclea to that of the Marchantiaceae, which was figured (but apparently not recognized) by RUGE ('93), but still GOEBEL does not definitely include Monoclea in that family.

CAMPBELL ('98) for the first time placed Monoclea definitely in the Marchantiaceae, because of the form of the thallus and the presence of two types of rhizoids, but especially because of the structure of the male receptacle and of the antheridium and archegonium.

Practically all the evidence collected in the present research seems to the writer to favor the view of CAMPBELL. For it is found that the thallus of Monoclea is like that of the Marchantiaceae in gross structure, in the mode of growth and branching, in the type of initial cell, and as I have been able to show in the possession of tuberculate rhizoids as well as thin-walled ones, in which latter character Monoclea differs from all described Jungermanniaceae.

These tuberculate rhizoids have been overlooked by earlier observers probably because of their comparative rarity, and because of the very few tubercles present in each rhizoid (*figs. 23, 24*). The tuberculate rhizoids are 10 to 15μ in diameter, while the other rhizoids are 25 to 35μ in diameter and much thinner walled. The distribution of these two types of rhizoids is perfectly constant, as was shown by LEITGEB ('77, p. 63). The thick-walled ones are scattered more generally over the thallus, and always lie nearly parallel to it, while the thin-walled ones are clearly grouped near the mid-line of the thallus and stand out perpendicularly to it (*figs. 8, 9, 28*). This is just the relative position of these two types of rhizoids in, for example, Marchantia or Fegatella (CAVERS '04, *fig. 17*), where the tuberculate rhizoids arise under the ventral scales along the whole costa and run backward between these scales to the base of the thallus, while the large, thin-walled ones arise in groups and stand straight out from the thallus.

The tuberculate rhizoids of Monoclea are always thin-walled near the distal end, which probably means that there is a long-continued growth in length in this region. Some of them surely reach a very great length.

The absence of the ventral scales characteristic of the other Marchantiaceae, and of the air chambers with their chlorophyll-bearing cells, is probably, as CAMPBELL has suggested, to be regarded

as a reduction due to the nature of the habitat of Monoclea. For, though these plants are not actually submerged, they do live in very wet places and are surrounded by a constantly saturated atmosphere. COKER ('03) has shown that we have an actual example of this sort of reduction in *Dumortiera hirsuta*, plants of which growing in a damp atmosphere on a porous, sandy soil, had well-developed air chambers, while other plants which were constantly wet with dripping water had no trace of such chambers. Even in Marchantia I find that, as was shown by RUGE ('93), submerged plants have imperfect air chambers or none at all. There seems also to be a marked reduction in the size of the ventral scales, in the number of tuberculate rhizoids, and likewise in the number of tubercles in them in these submerged plants.

The facts of vegetative structure referred to strongly indicate a relationship with the Marchantiaceae, and the structure and development of the reproductive organs seem to me to confirm this beyond reasonable doubt.

The male receptacle of Monoclea does not, it is true, closely resemble that of Fegatella, with which it has been most frequently compared, since it has but one growing point, while that of Fegatella has several, as has been shown by LEITGEB ('81, p. 95) and CAVERS ('04). In this respect Monoclea resembles much more certain other genera of the Marchantiaceae. In Corsinia, for example, according to BISCHOFF ('35, pl. 70) and LEITGEB ('79, p. 48), the antheridia arise acropetally on an elongated, thickened, and bordered receptacle very like that of Monoclea in origin and structure. Similar also are the less known male receptacles of Funicularia, according to MONTAGNE ('56), and of Sauteria, according to BISCHOFF ('35) and LEITGEB ('81). Among the higher Marchantiaceae also male receptacles similar to that of Monoclea are not wanting. Thus Aytonia (LEITGEB '81, GOEBEL '98), Reboulia (BISCHOFF '35, LEITGEB '81), Grimaldia (BISCHOFF '35, LEITGEB '81), and especially Fimbriaria (BISCHOFF '35, CAMPBELL '95) show a striking resemblance to Monoclea in the structure and development of the male receptacle. On the other hand there is no structure closely comparable with the male receptacle of Monoclea known among the Jungermanniaceae.

The development and structure of the sunken antheridia of Mono-

clea is still more clearly marchantiaceous in type. The large number of primary transverse divisions in the young antheridium, the mode of separation of the primary spermatogenous cells from the wall cells, and the elongated pointed form of the mature antheridium are, I believe, not found in any of the Jungermanniaceae.

The development of the archegonia directly upon the dorsiventral vegetative part of the thallus has, as was noted above, always been considered a most important difference between Monoclea and the Marchantiaceae, most workers having on this account compared it rather with the genera Pellia and Symphyogyna of the Jungermanniaceae. But even in this feature Monoclea is not without counterparts among the Marchantiaceae. For example, in Funicularia, according to LEITGEB ('79, p. 59) the archegonia are formed in groups of three or four, each group being sunken in a pit in the dorsal side of the thallus and protected by a hood-like involucre, which grows out over the archegonia from behind. Likewise in Corsinia, according to the same author ('79, p. 55), the archegonia arise acropetally in groups of eight or ten exactly as in Monoclea, and are also covered by a similar hood, which however seems to develop after fertilization. This hood may cover all the fertilized archegonia in one pit or there may be several hoods in the same pit, each covering one or more archegonia. In both genera of the Targionioideae (Targionia and Cyathodium) the archegonia arise directly behind the growing point of an ordinary branch of the thallus (LEITGEB '81, pp. 133 and 139, and CAMPBELL '95, p. 54). The two-lobed outgrowth of the thallus found here resembles in origin the involucre of Monoclea, though it remains quite small until after fertilization.

It seems more probable that in the case of Corsinia the wall of the pit as a whole is homologous with the involucre of Monoclea, rather than that each of the hoods is, but the most important character which Monoclea has in common with Corsinia, as well as with the other genera mentioned, is the development of the archegonia on an unspecialized portion of the thallus.

Of the archegonium of Monoclea I have already said that its development and mature structure are typically marchantiaceous. In the very long neck and especially in the six rows of neck cells it differs from all known Jungermanniaceae.

Probably the most serious obstacle of all to putting Monoclea in the Marchantiaceae has been the sporogonium, which with its long seta and its erect cylindrical capsule has quite the aspect of that of certain of the frondose Jungermanniaceae. But even here distinctive marchantiaceous characters are not entirely wanting. Thus, for example, the wall of the capsule of Monoclea is a single layer of cells (*figs. 31, 43*), except near the base and a small area at the top. In this respect it agrees with all known Marchantiaceae (SCHIFFNER '93), and differs from all the Jungermanniaceae with which it has been supposed to be related. For the wall of the capsule of Pellia is well known to be three or four-layered, and I have found that of Symphyogyna to have a similar structure, instead of a one-layered wall as is stated by SCHIFFNER. The slightly developed foot of Monoclea has many counterparts among both Marchantiaceae and Jungermanniaceae. The seta is probably longer than is found in any other marchantiaceous form, but this and the simple type of rupture of the capsule, which occurs in isolated cases in both the Jungermanniaceae and Anthocerotaceae, are perhaps related in some way to the peculiar habitat of the plant. The spores and elaters show, so far as I have discovered, no characteristic peculiarities.

The particular genus of the Marchantiaceae to which Monoclea is most closely related I am at present unable to suggest. We have seen that it resembles certain of the simpler genera in the place of origin of its antheridia and archegonia. These facts seem to me to favor CAMPBELL'S view ('98) that the relationship of Monoclea is with the lower Marchantiaceae. The occurrence of similar male receptacles in some of the higher forms, *e. g.*, Fimbriaria and Grimaldia, is probably an instance of the persistence of the primitive type of male receptacle side by side with a more highly specialized female one.

SUMMARY.

Monoclea occurs in Jamaica in very damp places, being usually constantly wet with dripping water.

The male receptacle of Monoclea is only superfically like that of Fegatella, since all the antheridia of a receptacle are formed in acropetal succession from one growing point. It resembles rather that of Corsinia and Fimbriaria.

The antheridium rudiment is elongated, and it divides transversely into six or seven primary cells. The wall cells and spermatogenous cells are separated from each other in the body of the antheridium after the formation of quadrant and octant walls. The mature antheridium is elongated and pointed and is sunken in the receptacle.

In the nucleus of the spermatozoid the individual chromosomes are recognizable as distinct twisted fibers.

The archegonium is very long-necked, has six rows of neck cells and twelve or more neck canal cells. It is probably fertilized before the hood-like involucre has grown far beyond its tip.

The capsular portion of the sporogonium divides to quadrants and octants before sporogenous cells and wall cells are separated. The foot is small, the seta stretches to 30 or 40^{mm} in length, and the extended capsule is erect, elongated, cylindrical, and its wall is a single layer of cells.

Monoclea possesses two kinds of rhizoids, corresponding to those of Marchantia in size, direction of growth, and in the presence of tubercles in those of one type.

The absence of air chambers and ventral scales is probably due to the nearly aquatic habit of the plant.

The evidence gained from the study of the origin and structure of the male receptacle, and of the antheridium and archegonium, and from the structure of the wall of the capsule, and the presence and direction of growth of the two types of rhizoids, favors the view that Monoclea is most closely related to the lower Marchantiaceae.

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EXPLANATION OF PLATES XVI AND XVII.

PLATE XVI.

FIG. 1. View of upper surface of part of a male thallus, showing branching and three generations of male receptacles. ×1.5.

FIG. 2. Transverse section of a male plant through a mature receptacle. ×5.

FIG. 3. Longitudinal section of male plant through receptacles of two generations. ×3.

FIG. 4. Diagrammatic view of upper surface of a half-grown male receptacle with a single growing point; the dotted outlines indicate the location of the antheridia. × 25.

FIG. 5. Similar view of a male receptacle with two growing points. × 25.

FIG. 6. Upper anterior part of a longitudinal section of a young male receptacle, showing very young antheridia. × 350.

FIG. 7. Longitudinal section of a young male receptacle, passing just at one side of the growing point; the dotted lines indicate the position of the growing point in an adjoining section. × 38.

FIG. 8*a*. Surface view of nearly mature spermatozoid, showing the intertwisted chromatin fibers. × 1500.

FIG. 8*b*. Diagram of an optical section of such a spermatozoid, showing the relation of chromatin fibers still more clearly. × 4000.

FIG. 9. Median longitudinal section of an older male receptacle; the letters indicate the order of origin of the antheridia. × 30.

FIG. 10. Young antheridium and surrounding cells from a section similar to last. × 350.

FIG. 11. Longitudinal section of a young antheridium, showing the seven primary tiers of cells and the separation of the wall cells from the spermatogenous cells. × 350.

FIG. 12. Similar section of a slightly older antheridium. × 350.

FIG. 13. Similar section of an antheridium and an antheridial cavity of the male receptacle. × 350.

FIG. 14. Longitudinal section of an older antheridium. × 160.

FIG. 15. Transverse section of a young antheridium and surrounding cells showing a primary longitudinal wall of the antheridium. × 650.

FIG. 16. Similar section of an antheridium showing quadrant walls. × 650.

FIG. 17. Similar section of an antheridium in which spermatogenous cells and the antheridial wall have been differentiated. × 650.

FIG. 18. Transverse section of an older antheridium, showing the mode of division of the four primary spermatogenous cells. × 350.

FIGS. 19–20. Similar sections of still older antheridia, showing multiplication of spermatogenous cells. × 160.

FIG. 21. Portion of longitudinal section of nearly mature antheridium, showing the wall and the three-cornered spermatozoid mother-cells. × 350.

FIG. 22. View of the upper surface of part of a female plant, showing an involucre containing two young sporogonia, one containing a nearly full-grown sporogonium, and one from which a capsule has already been extended. × 1.5.

FIGS. 23–24. Optical longitudinal sections of tuberculate rhizoids. × 650.

FIG. 25. Portion of the edge of the thallus with thick-walled marginal rhizoids. × 160.

FIG. 26. Longitudinal section through the growing point of a female plant, showing the beginning of the pit in which the archegonia arise. × 75.

PLATE XVII.

FIG. 27. Lower portion of the same section, showing the slime-secreting hairs and the cells which are to form archegonia. ×350.

FIG. 28. Longitudinal section of an older archegonial pit, showing the half-grown involucre and two mature archegonia. ×38.

FIG. 29. Similar section of a full-grown involucre, containing an archegonium with a young embryo. ×8.

FIG. 30. Transverse section of fertile branch of female thallus passing through an involucre containing a nearly mature sporogonium. ×8.

FIG. 31. Longitudinal section of similar involucre and sporogonium. ×8.

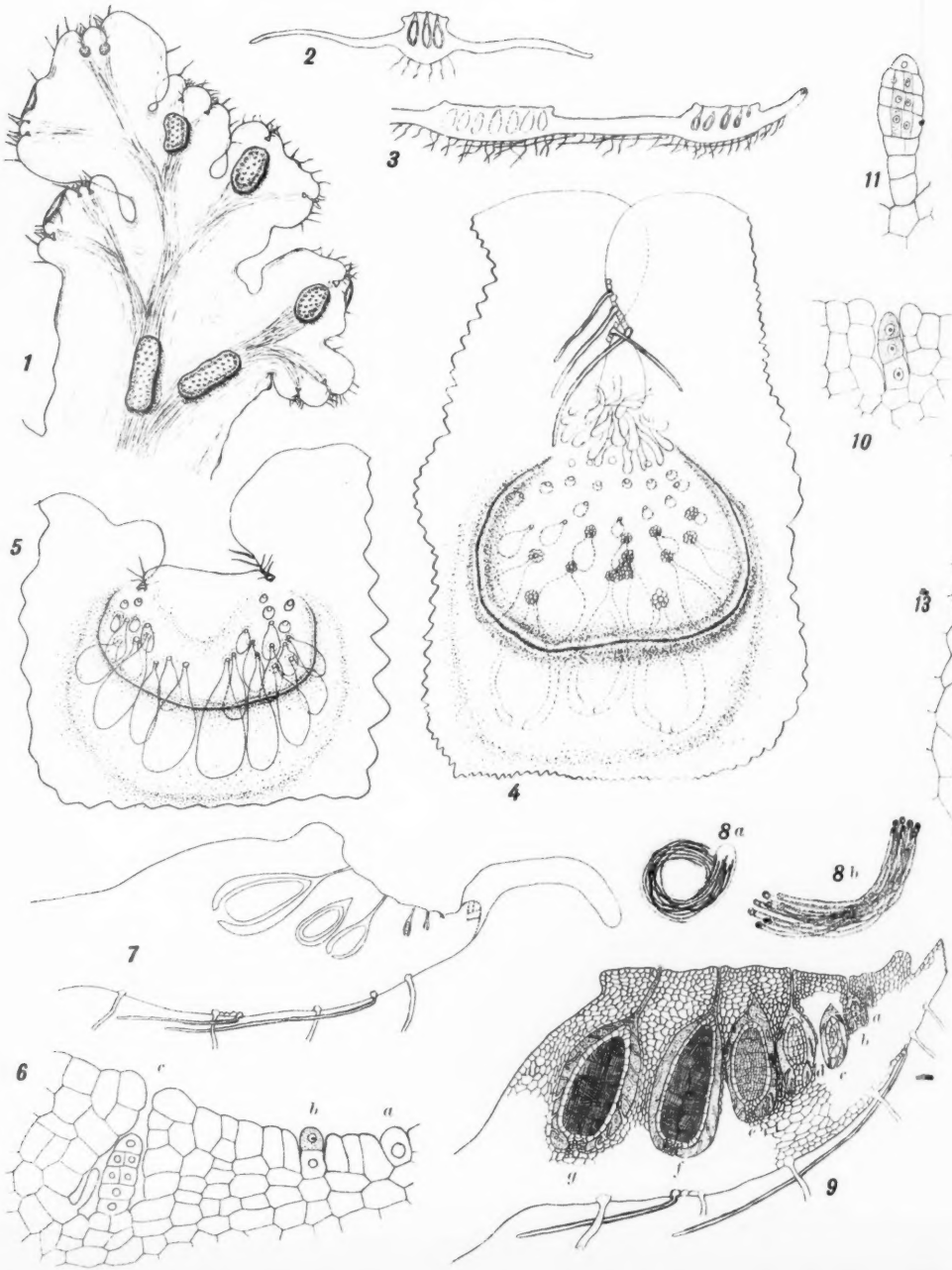
FIG. 32. Longitudinal section of a young archegonium. ×350.

FIG. 33. Longitudinal section of a mature archegonium. ×160.

FIG. 34. Transverse section of neck of archegonium, showing eight neck cells. ×160.

FIG. 35. Similar section of archegonium at juncture of neck and venter, showing a normal six-celled neck. ×300.

FIGS. 36–37. Longitudinal sections of young embryos, showing the earlier walls in the latter. ×350.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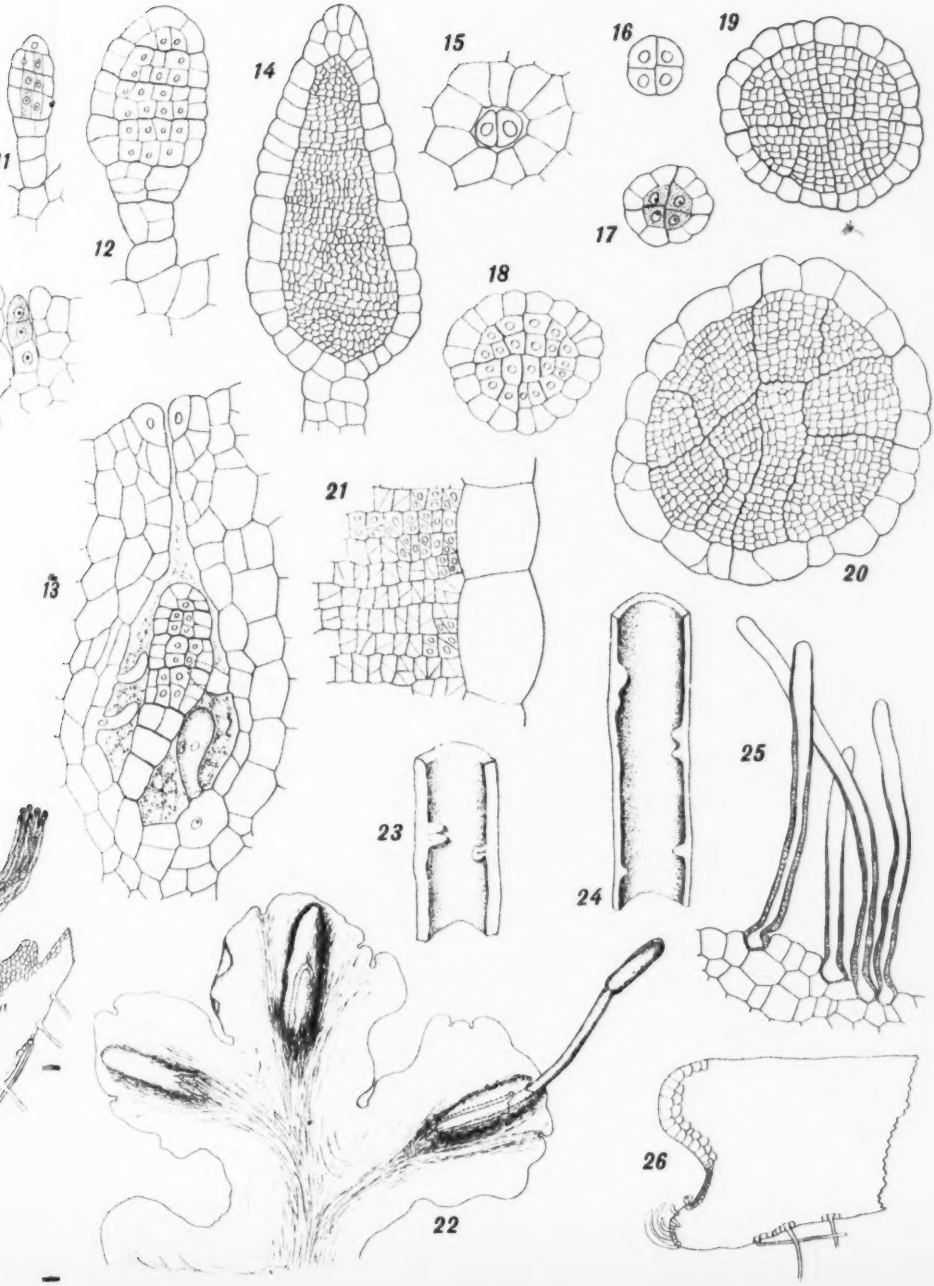
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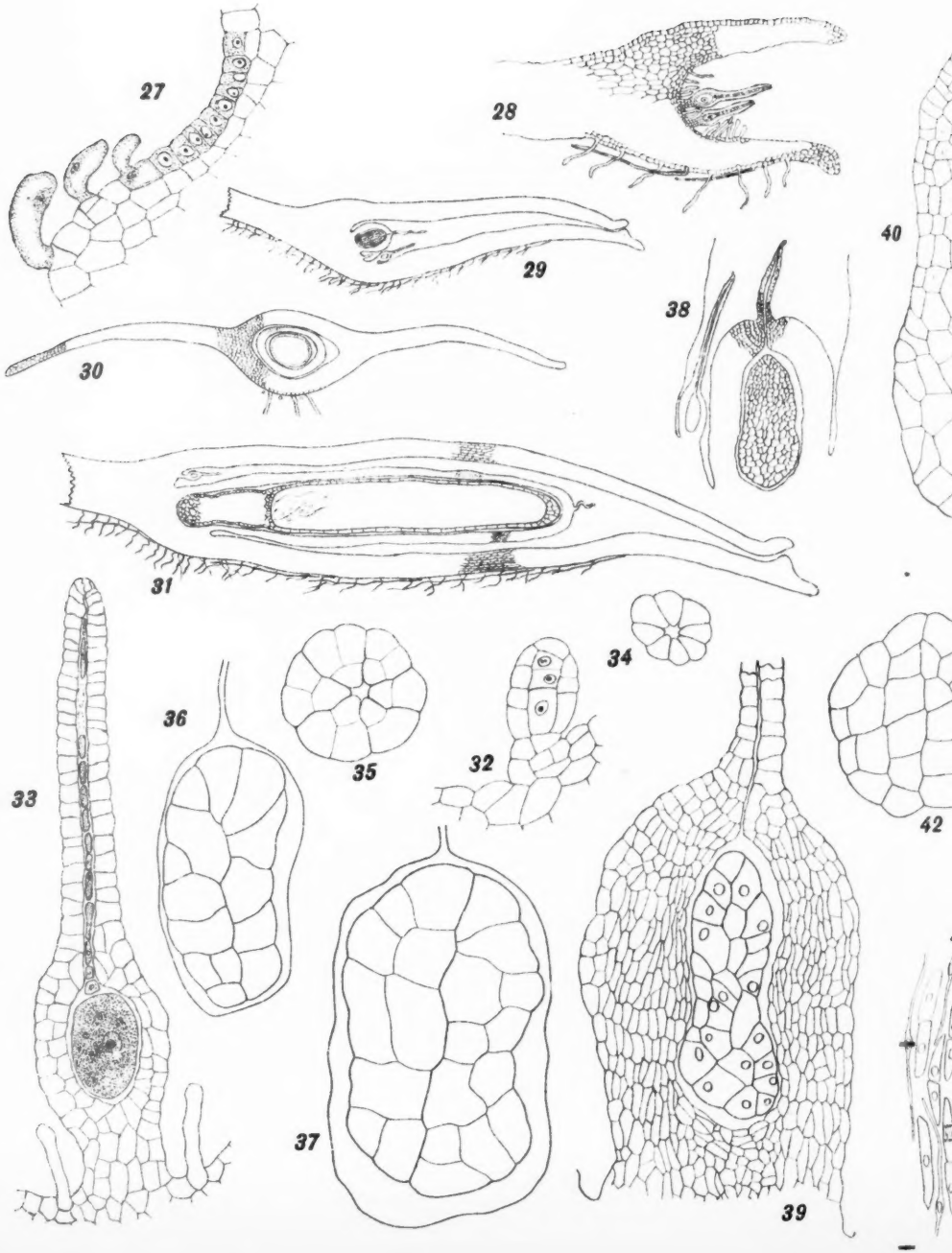
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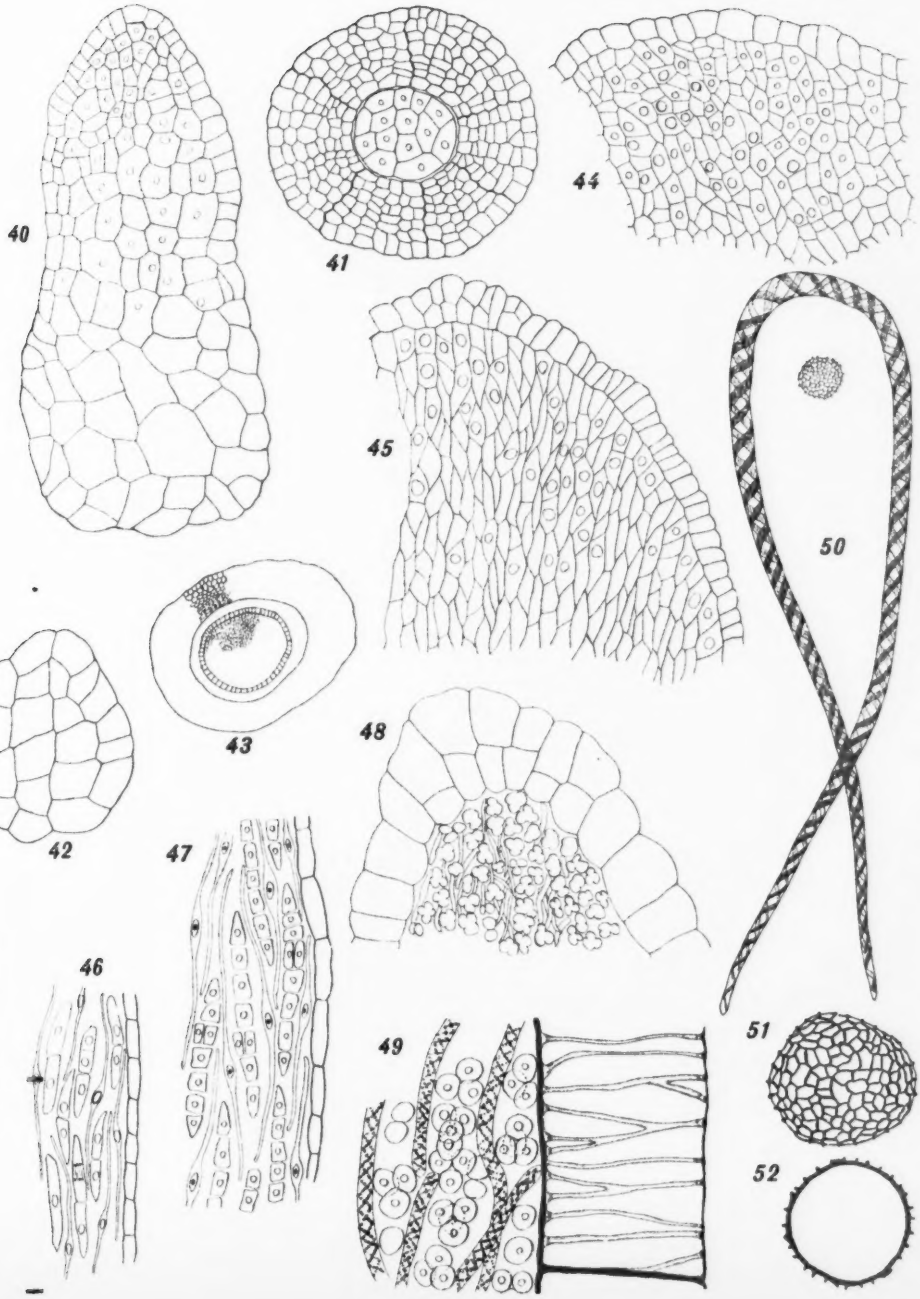


on MONOCLEA.

FIG. 38. Longitudinal section of young embryo and archegonium. ×38.

FIG. 39. Similar section with a slightly younger embryo, showing the differentiation of the latter into foot, seta, and capsule. ×160.

FIG. 40. Longitudinal section of an older embryo, showing differentiation of capsule into wall and sporogenous cells. ×160.

FIG. 41. Transverse section of an archegonium and embryo of the age of that shown in *fig.* 37, showing arrangement of cells in the capsular region. ×160.

FIG. 42. Similar section of another embryo. ×160.

FIG. 43. Transverse section of an archegonium, with an embryo showing wall of capsule and isodiametric sporogenous cells. ×38.

FIG. 44. Detail of last. ×350.

FIG. 45. Part of longitudinal section of a capsule of the same age as the last. ×350.

FIG. 46. Part of a similar section of an older capsule, showing elaters and their spindle-shaped sister cells dividing to spore mother-cells. ×350.

FIG. 47. Similar figure from an older capsule, showing elaters and rows of spore mother-cells. ×350.

FIG. 48. Longitudinal section of the tip of a nearly mature capsule, showing two-layered region of the wall and three-lobed spore mother-cells. ×160.

FIG. 49. Elaters, tetrads of spores and a cell, from the wall of a still more mature capsule. ×350.

FIG. 50. Single elater from a ripe capsule. ×700.

FIG. 51. A single spore showing structure of spore wall. ×1250.

FIG. 52. Optical section of spore wall. ×1250.

ON THE SPORES OF CERTAIN CONIFERAE.

W. C. Coker.

(WITH TWENTY-FOUR FIGURES)

The pollen grain.—There is much greater diversity in the male gametophyte of gymnosperms than of angiosperms. Such forms as Thuja, Taxodium, and Taxus have this structure so much reduced as closely to resemble, in the number of cells formed, the pollen grains of the flowering plants. Others, as Ginkgo, Pinus, and Podocarpus, contain, sooner or later, as many as six nuclei in the pollen grain and tube. In my paper on Taxodium I have summarized the present knowledge on this point in gymnosperms, and it is seen that much yet remains to be done before the structure of the pollen tube is understood in all genera.

During the spring of 1902, while in Bonn, I examined almost daily the maturing pollen grains of a number of conifers, and followed them to the time of shedding. This was for the purpose of settling the point as to whether it were possible that a sterile prothallial cell or cells might be cut off early in development and, becoming disorganized, be overlooked in the ripe grain.

In the following species it was found that no division whatever occurred in the pollen grains while they were in the sporangium, and that they were shed in the one-celled stage: *Cupressus Goveniana*, *C. macrocarpa*, *C. Benthamiana*, *Taxus baccata* and vars. *epacrioides*, *fastigiata*, *cuspidata*, and *adpressa*, *Juniperus sphaerica*, *J. chinensis*.

In *Cupressus sempervirens*, pollen from a tree growing in the warm-house showed a division while still in the sporangium; but this variation from the rule in this genus probably resulted from delay in the dehiscence of the sporangium, caused by the unnatural conditions. It could easily be seen that dehiscence did not occur promptly and in some cases was only partial. Pollen grains of *C. Benthamiana* placed in sugar solution divided in a few cases in about a week.

In the following species there was one division of the pollen just

before shedding: *Chamaecyparis Lawsoniana pendula, C. sphaeroidea, C. chinensis, C. obtusa, C. pisifera, Callitris* sp., *Cryptomeria japonica* and var., *Thuja orientalis.*

The fate of these pollen cells was not followed further, but the appearance of the small cell cut off before shedding is quite unlike that of a prothallial cell, and bears every resemblance to the single (generative) cell cut off at the same time in Taxodium, where certainly no prothallial cell is formed. Furthermore, in all cases where prothallial cells are known to occur, they are produced while still in the sporangium, and the divisions that cut them off are immediately followed by another which gives rise to the generative cell. It is hardly to be doubted, therefore, that no prothallial cell is formed at any time in the species above mentioned.

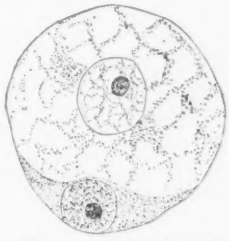
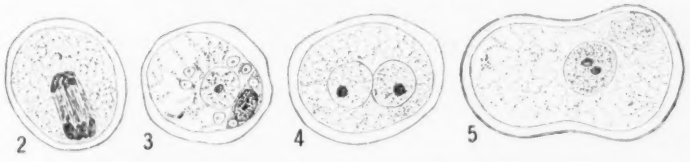


FIG. 1. *Thuja orientalis;* pollen grain ready to shed. × 1700.

In *fig. 1* is shown the mature pollen grain of *Thuja orientalis*, the exine not being drawn. The generative cell is of the usual structure and is sharply separated from the rest of the contents. Its nucleus is as usual more dense than the tube nucleus. In *fig. 2* the pollen grain of *Cupressus sempervirens* is represented in division, while in *fig. 3* the division is completed. In this last figure a few starch grains are shown. In most cases the generative cell is free from starch even



FIGS. 2–5. *Cupressus sempervirens; fig. 2*, pollen grain in division; *fig. 3*, same ready for shedding; *figs. 4* and *5*, abnormal pollen grains. × 750.

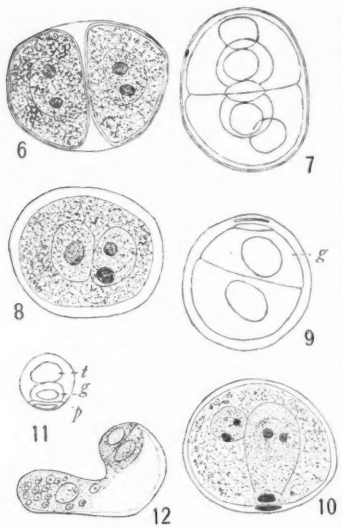
in pollen where it is abundant, but here (*fig. 3*) it also contains a few scattered grains.

It will be seen that the above results confirm to a large extent STRASBURGER'S observations on mature pollen. He finds[1] that in

[1] Ueber das Verhalten des Pollens, etc. 1892.

species of Taxus, Cupressus, and Juniperus the pollen grain divides only after reaching the nucellus; while in Thuja, Cephalotaxus, Podocarpus, Chamaecyparis Lawsoniana, Cryptomeria, Sequoia, Araucaria, and the Abietineae it divides before shedding.

In examining so many pollen cells it was not surprising that a good many abnormal forms were met with. In Cupressus it happened not infrequently that the generative nucleus was not cut off in a separate cell of its own, but remained free in the general cytoplasm, side by side with the pollen tube nucleus. In such cases (*fig. 4*) the two nuclei were so much alike as to be hardly distinguishable. In *fig. 5* is illustrated a pollen grain of peculiar shape and about twice the normal size. The generative cell, however, is of the usual appearance. It will be remembered that the tree from which this pollen was taken was not growing in perfectly congenial surroundings, and this may account for the rather unusual number of abnormalities.



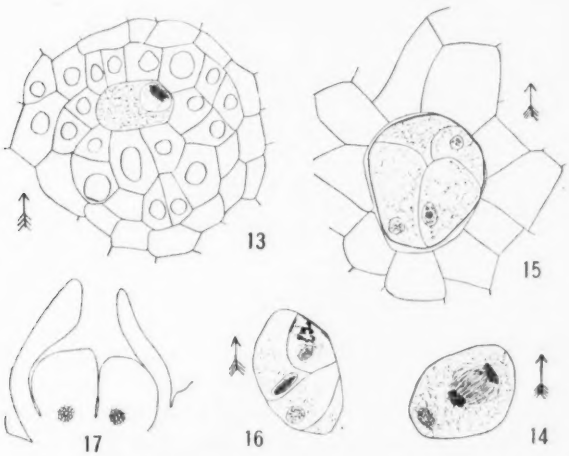
FIGS. 6–10. *Larix europaea; figs. 6–9*, abnormal pollen grains; *fig. 10*, normal grain. × 315. FIGS. 11, 12. *Encephalartos* sp.; *fig. 11*, shed pollen grain; *fig. 12*, sprouting grain. ×315.

In *Larix europaea* a number of cases were found in which the mother-cells had divided but once, so that only two instead of four pollen grains were formed (*fig. 6*). In some of these double grains the divisions proceeded about as usual. *Fig. 7* gives such a case, but here only one prothallial cell is evident. Abnormal grains with two large free nuclei were also found (*fig. 8*). In *fig. 9* a generative cell (*g*) of very unusual appearance is shown. For the sake of comparison a drawing is given of the normal pollen grain of Larix (*fig. 10*).

In *Encephalartos* sp.? the mature pollen grain contained one prothallial cell, *p*, a generative cell, *g*, and a tube cell, *t* (*fig. 11*). No

starch was found at this stage, but when the pollen was put in sugar solution it made its appearance in about two days. A sprouting grain that had been in sugar solution six days is shown in *fig. 12*. Here the prothallial cell and the generative cell are changed in position and the tube nucleus has moved down, and is surrounded by starch. One prothallial cell has been found in Ceratozamia, Zamia, and Cycas.[2]

THE MEGASPORE AND EMBRYO SAC.—In the Cupressineae there is practically nothing known of the behavior of the megaspore mother-



FIGS. 13–17. *Thuja orientalis; fig. 13*, megaspore mother-cell surrounded by spongy tissue, × 335; *fig. 14*, megaspore mother-cell during first division, × 525; *fig. 15*, tetrad of megaspores, × 525; *fig. 16*, the same, × 525; *fig. 14*, abnormal ovule with two sporongia, × 43.

cell or of the origin of the megaspore. In Taxodium, which I consider as belonging to this group, the megaspore mother-cell divides into three potential spores, the largest of which is functional. As to other members of the group there is scarcely any literature that treats of this stage. STRASBURGER[3] remarks that in Thuja the origin of the embryo sac is essentially as in Taxus.

[2] The literature on this point is cited in my paper on Taxodium.

[3] Die Angiospermen und die Gymnospermen. 1879.

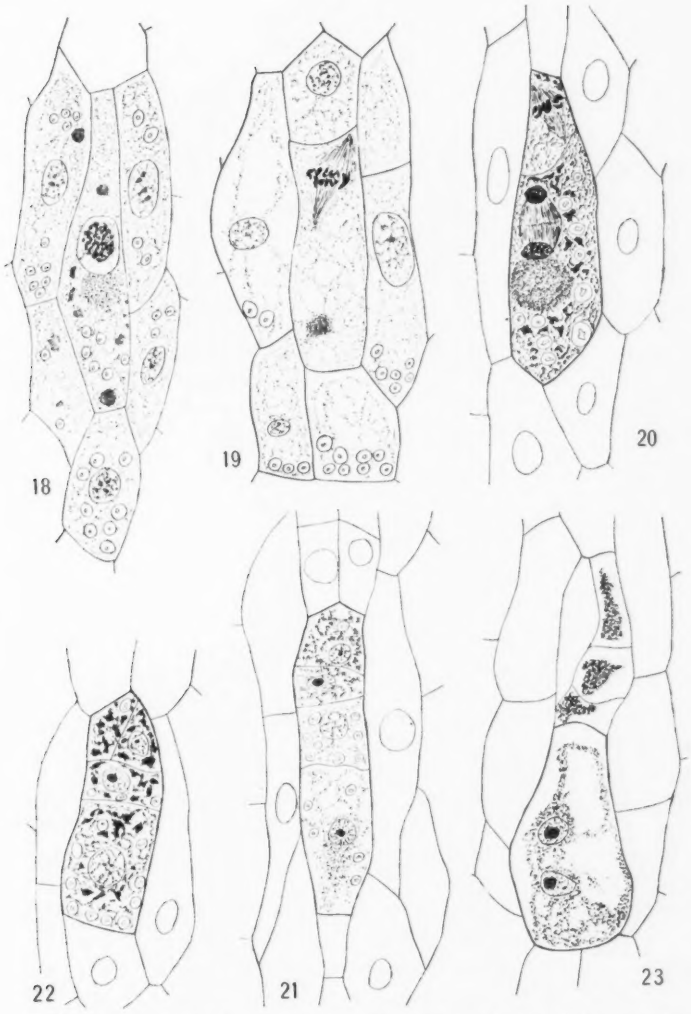
Thuja.—In the hope of settling these points in some member of the Cupressineae, young ovules of *Thuja orientalis* were collected and sectioned in Bonn. The megaspore mother-cell soon becomes evident among the conspicuous spongy tissue. It has thicker walls and is also less dense than the cells around it. Its position is not always in the center of the spongy tissue, and its long diameter is as often as otherwise at right angles to the longitudinal axis of the ovule (*fig. 13;* the arrow shows the direction of the axis of the ovule). Occasionally there are two or three mother-cells developed, and in such cases they are generally separated by cells of the spongy tissue. In *fig. 13* the mother-cell nucleus is in synapsis, and in *fig. 14* the first division spindle is shown. There is the same kinoplasmic mass at the lower end of the cell as in *Larix sibirica*[4] and Taxodium. The spindle of the next division was not seen, but the result is shown in *figs. 15* and *16*. Four megaspores are produced and their arrangement is more nearly that of the typical tetrad than in any other gymnosperm in which this stage has been described. After the completion of the last division, the spores may be seen packed together within the still nearly round mother-cell. They are never in a straight row, but are so arranged that in thin sections no more than three nuclei appear at once. The mother-cell wall around them also stains more deeply than those of the neighboring cells, so that the appearance approaches very closely what is found in the divided mother-cell of ferns. None of the spores is conspicuously larger than the others, and it was not determined which one became functional.

A peculiar abnormality in the ovule of *Thuja orientalis* is given in *fig. 17*. Two separate nucelli are present within the same sporangium and each has the usual sporogenous area. In other cases two fused sporangia were found in the same ovule, the sporogenous areas still being distinct. I have a preparation showing the same peculiarity in the ovule of *Erythronium americanum;* the nucellus is two-lobed and contains an embryo sac in each lobe.

Taxus.—Strasburger finds[5] several megaspore mother-cells developed, and says that one or more of them divide into three or rarely

[4] JUEL, H. O., Beiträge zur Kenntniss der Tetradentheilung. Jahrb. Wiss. Bot. **35**:626–659. *pls. 15–16.* 1900.

[5] Die Angiospermen und die Gymnospermen. 1879.



FIGS. 18–23. *Taxus baccata; fig. 18*, megaspore just before division, nucleus in synapsis, × 675; *fig. 19*, same during first division, × 675; *fig. 20*, spindles of second division, × 675; *fig. 21*, four potential megaspores in a row, × 525; *fig. 22*, four potential megaspores, the upper lying side by side, × 525; *fig. 23*, sprouting of lower megaspore, × 625.

more cells lying in a row. JÄGER[6] with some hesitation agrees with STRASBURGER that there are three or four megaspores formed from the mother-cell; but it is pretty evident from his figures that he had before him not the spores, but the mother-cells and sterile tissue. JÄGER also seems to agree with STRASBURGER that there may be several megaspore mother-cells. I cannot confirm these two observers as to the number either of the megaspore mother-cells or of the potential megaspores into which they divide. In my preparations there is no evidence that there is ever more than one megaspore mother-cell formed. The mother-cell is here harder to distinguish than in any other plant I have seen. At the time its first division occurs, it is long and narrow, resembling closely in shape the cells adjoining (*figs. 18* and *19*). It differs from them, however, in the possession of a rather conspicuous kinoplasmic mass near its lower end, resembling in this respect the mother-cells in Larix, Taxodium, and Thuja. Very rarely there is another smaller kinoplasmic mass above the nucleus. In *fig. 18* the mother-cell is shown in the center with its nucleus in synapsis. The first division is given in *fig. 19*. The spindle as here shown is at the upper end of the cell, and the division results in cutting off a small upper and a large lower part. The second division occurs simultaneously in both of these daughter-cells, as is shown in *fig. 20*. This results in the formation of four potential megaspores, which lie as a rule in a single row (*fig. 21*). The second division in the upper daughter-cell of the first division, however, may in some cases be at right angles to the longitudinal axis of the ovule, so that the two upper megaspores lie side by side (*fig. 22*). The long, narrow cells adjoining the megaspore mother-cell, which as mentioned above are well filled with starch, have remained undivided during these divisions. In some cases they divide into two, but they never resemble

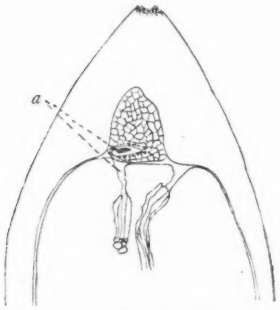


FIG. 24. *Taxus canadensis;* two prothallia in same ovule; embryos in lower, disorganizing archegonium in upper. × 43.

[6] Beiträge zur Kenntniss der Endospermbildung und zur Embryologie von *Taxus baccata*. Flora **86**: 241–288. *pls. 15–19*. 1899.

the megaspore mother-cells, nor do their divisions give rise to cells resembling the megaspores. There seems no doubt that STRASBURGER and JÄGER were wrong in giving the number of megaspores as generally three.

In addition to *Taxus baccata* and *Thuja orientalis* (as here shown) there are but three other conifers in which four potential megaspores have been definitely described. They are *Larix sibirica*, *Pinus Laricio*, and *Sequoia sempervirens*.[7]

As mentioned above, there is no spongy tissue surrounding the megaspore mother-cell in Taxus, and as the lower megaspore develops in sprouting, it crushes aside and destroys the cells immediately adjoining it, eating its way gradually into the more distant layers (*fig. 23*).

HOFMEISTER observed many years ago that more than one embryo-sac may occur in Taxus, and this I have found to be not uncommon in *Taxus canadensis*. Here one of the two prothallia, when two are present, is usually much smaller than the other. It is interesting to find that both prothallia may bear archegonia (*fig. 24, a*). The archegonia in the upper prothallium face towards the lower prothallium and not toward the micropyle, showing that the upper prothallium is inverted. The pollen tube does not stop at the upper end of the nearest prothallium, but growing past it presses in between the two to reach the archegonia. In all such cases it was the archegonia of the lower prothallium only that were fertilized (*fig. 24*).

In conclusion I wish to thank Professor STRASBURGER for his valuable advice and unfailing kindness.[8]

[7] See my paper on Taxodium for literature.

[8] The drawings have been inked in by Mr. H. A. Allard under my direction.

BRIEFER ARTICLES.

ARTIFICIAL PARASITISM: A PRELIMINARY NOTICE.

SOME years ago, in the course of an investigation suggested by PFEFFER to show that ordinary roots, as well as those of parasites, can penetrate living tissues, I succeeded in growing a pea (*Pisum sativum*) on a plant of horse-bean (*Vicia Faba*), at least so far that the pea blossomed and set seed.[1] At intervals since that time I have grown peas on plants of the same bean, with success varying according to the very unideal conditions under which I have experimented. Some of the results obtained seem worthy of publication now, although I have only begun a piece of work which I hope to carry on for years to come.

The main object of the investigation is to ascertain how an independent plant will behave when compelled to lead a parasitic or partially parasitic existence; what the changes, immediate, successive, and cumulative, may be in successive generations.

The method so far pursued is this. Pea seeds of "extra early" varieties, soaked in water for twenty-four hours, are placed, radicle downward, in bulb pots of fine sand, and allowed to germinate until the radicles are 1–2^{cm} long. The seeds are now ready for setting on the beans. These are plants of *Vicia Faba*, 30^{cm} or more tall, grown two or three in each pot. Care is taken to select for experiment only strong plants, although I cannot see that the peas injure the beans on which they grow. At a height of about 15^{cm} above the soil I cut a hole, with a taper-pointed, sharp, clean scalpel, in the stem of the bean, the hole being about as large as the radicle of the pea selected for mounting on the bean plant. Into this hole the radicle is gently pushed, passing into the cavity of the hollow stem, until the cotyledons are close against the stem. A strip of writing paper is now so wrapped about the stem and fastened with sealing wax as to form a conical mold. Into this plaster of Paris is poured until it all but covers the cotyledons. In this way the pea is held in place without interfering with the upward growth of the plumule. In dry weather the molds are made deep enough to hold a layer of wet saw-dust 1^{cm} or more deep over the plaster. This is unnecessary, however, in damp weather. When the pea-plants are 5^{cm}

[1] PEIRCE, G. J., Das Eindringen von Wurzeln in lebendige Gewebe. Bot. Zeit. **52**: 169–176. 1894.

or so high, I take off the paper and plaster, cut off the cotyledons, and thus force the peas to draw all their water and mineral salts from the bean plants. This they do successfully.

By such a simple method as this I compel peas to live on bean-plants in essentially the same degree of parasitic dependence as that of Viscum or Phoradendron upon oaks. What are the results? These will be shown by extracts from my laboratory notes.

January 27, 1902. Peas set November 12 on beans and in dirt in same boxes began to bloom; one flower on a bean-pea, several on soil-peas. Great difference in size of plants, number and area of leaves, size of flower and of parts of flower, between bean-peas and soil-peas. Weather since November 12 dry and cold for the most part.

These plants were grown out of doors in a cold frame on the southwest side of the laboratory building. The frame was usually open from nine or ten o'clock until four or five daily, the hours of opening and closing depending mainly upon the temperature. The boxes used were shallow and the soil poor. The soil-peas were about half the size which the plants of the same variety would attain later in the season in rich soil of proper depth. The bean-pea plants were about one quarter to one half the size of the soil-pea plants growing in the same boxes, but were well proportioned and stocky.

From these plants I harvested a crop of ten good seeds from the bean-peas and ninety-three from the soil-peas. On the bean-peas there were only two or three peas in a pod, and the pods were small and rather thin, splitting normally when dry.

These pea-seeds I subsequently measured by vernier caliper. The air-dry, ripe seeds were not uniform in shape, and rather than take the largest diameter in each case I decided to measure through the same points, as nearly as possible, in each seed, viz., on a line bisecting the hilum at a right angle, holding the hilum toward my lefth and, the caliper being in my right. Of the bean-peas three were decidedly smaller than the rest.

Thickness of smallest bean-pea seed	5.25^{mm}
Thickness of largest bean-pea seed	6.95
Average thickness of 10 bean-pea seeds	6.31
Average thickness of 7 larger bean-pea seeds	6.66
Average thickness of 3 smaller bean-pea seeds	5.48

I measured similarly the 93 seeds, ripe and air-dry, which I had gathered from the pea-plants grown in the soil. Three of these peas were more than 8.00^{mm} in thickness, one was 5.12^{mm}. This last was smaller than any bean-pea. There were also fifteen among these soil-peas which were

less than 6.00^{mm} in thickness. The average thickness of 93 soil-peas was 6.88^{mm}.

The weights, air-dry, of the bean-peas and soil-peas were

	Bean-peas	Soil-peas
Total weight	1.709^{gr}	20.111^{gr}
Mean weight	0.170	0.216
Largest weighed	0.227	0.337
Smallest weighed	0.090	0.119

Comparing these sizes and weights of the seeds with the sizes of the plants, we see that the individual seeds are much less reduced in size and weight by the enforced semi-parasitism of the parents than are the vegetative parts.

I subsequently soaked these seeds, the ten and the ninety-three, in separate dishes of tap-water, for twenty-four hours. The bean-peas then weighed 3.363^{gr}, the soil-peas 32.449^{gr}. The bean-peas, therefore, gained 1.967 times their weight, the soil-peas 1.613 times. From this it may be inferred that the bean-peas either were thinner skinned or contained more actively absorbing substances than the soil-peas. Which was the case I cannot tell.

The bean-peas were then placed (2:00 P.M., May 5, 1903) in wet sphagnum to root. On May 6, 4:00 P.M., good normal roots 1^{cm} long had been formed by six of these seeds. I mounted them, as before described, on potted plants of *Vicia Faba*. The following morning three more were set on the bean plants. I broke the root of one of the ten seedlings in mounting it, and therefore threw it aside. Thus I had, mounted on bean plants, nine seedlings of peas grown the previous year on bean plants. These seedling peas, therefore, had never been in contact with the soil. Nevertheless, in the tap-water and especially in the sphagnum there was a certain amount of "dirt." This could be avoided, and will be in future experiments.

During the succeeding weeks these peas grew into little plants, somewhat smaller than those of the preceding season, but well proportioned and healthy-looking. I moved them from the laboratory to my own garden, where they would be watered during the summer vacation and where I could watch them, but unfortunately a dog or some other creature played havoc with my beans one day while I was away from home, and my experiment was ended.

Something should be said, even in such a superficial account as this, about the roots of the peas grown on beans, and of the relations of these roots to the tissues of the beans. There was no tissue union between host

and parasite as in natural semiparasites like Viscum and Phoradendron. The roots grew downward through the internodes and nodes, but did not, in any case here reported, reach the level of the soil, much less reach the soil itself. The roots branched much less freely than normal soil roots, were closely applied to the walls of the hollow internodes, and did not at any point fill the cavity of the internode.

That this much reduced root-system sufficiently supplied the small bean-pea plants with water is proved by an accidental experience. The potted bean plants one day became dry enough to wilt, but the peas were perfectly fresh and turgescent. The beans recovered promptly when watered and the peas at no time showed any ill effects.

It may be claimed that the smaller size of the pea-plants grown on beans is due to hard times—to mechanical interference with the normal growth and development of the root system. This may be true, but it is equally true that there are mechanical hindrances to the growth, extension, and development of the root systems of all phanerogamic parasites. In this respect, therefore, the cases are parallel.

In the aerial parts of Viscum, Phoradendron, and Arceuthobium,[2] xerophytic characters are evident.[3] These did not appear in my bean-peas, unless the smaller number and size of the leaves and the shortened internodes may be so called. Xerophytic characters may appear later if peas are cultivated on beans through a series of generations. I hope to be able to do this, under conditions which can be carefully controlled, and especially where my plants may at least be protected against ordinary accident.

I have tried various other seeds on *Vicia Faba*, including *Vicia Faba* itself, but peas have so far done best and *Vicia Faba* has proved to be the best host for them. A more succulent plant with solid stem, however, would be better. This I shall try in the future.

Though this is an incomplete account of experiments far from concluded, it has seemed best to put this much of my work on record. It may throw a little light on questions regarding the beginning of parasitism, the immediate effects of removing the roots of green plants from their normal medium, the soil, and compelling these green plants to supply themselves with water and mineral matters from other plants.—GEORGE J. PEIRCE, *Stanford University, California.*

[2] I expect presently to publish a paper on Arceuthobium.

[3] CANNON, W. A., The anatomy of *Phoradendron villosum*. Bull. Torr. Bot. Club **28**: 374–390. *pls. 27–28*. 1901.

THE GROWTH OF RAMALINA RETICULATA.

(WITH ONE FIGURE)

RAMALINA RETICULATA (Noehd.) Krempelh., so characteristic of the coast valleys of California, offers to the plant physiologist a particularly fruitful field for the study of the growth, apothecial development, and dissemination of lichens.

TUCKERMAN states[1] that his longest specimens were a little more than a foot in length, and that the widest perforated expansions exceeded 20mm. Just what dimensions this plant may attain I am not prepared to state, but I agree with Dr. Peirce that it is probably the largest of our North American lichens. Specimens four and five feet long are common on the trees about Stanford University, their widest perforated expansions reaching two feet or more. Specimens in my herbarium vary from those of the most delicate lace-like structure to those having broad, unperforated expansions 25 to 40mm in width, dimensions much greater than the largest perforated specimens seen by Tuckerman. *Usnea longissima* Ach. attains a length of eight or nine feet on the redwoods of the Santa Cruz mountains, but the thallus is so slender that its real size is much less than that of *Ramalina reticulata*.

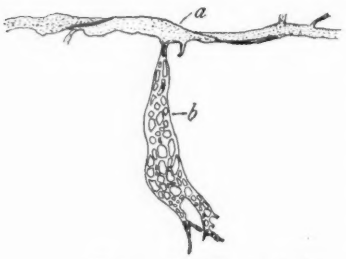


FIG. 1.—*Ramalina reticulata: A*, thallus branch; *B*, lobe; *C*, knot of silk used to designate measured lobes.

The plant is evidently such a rapid grower that last September a series of measurements were made, at the suggestion of Dr. G. J. Peirce, in order to obtain some definite results. The lengths in the column under September are the measurements made September 25, 1903; those under May were made May 5, 1904, an interval of seven months and ten days. The winter rains did not begin for nearly two months after the measurements were made, and ceased two or three weeks before the lichens were remeasured, so that most of the growth was confined to a period of about five months. During the late winter and early spring growth must have been both rapid and continuous, since for nearly two months it rained almost daily, the temperature also being favorable for growth.

The thallus was measured from the point of attachment, the lobes measured being marked by a knot of silk thread, the weight of which was so inconsiderable as to have no effect on the growth. The measurements

[1] Synopsis N. A. Lichens, part 1, p. 22.

were of two kinds, the entire thallus, and individual lobes (*fig. 1*). To obtain the best results they should all be of the latter kind, as owing to the constant breaking off of long plants it is impossible to be sure of results, or even to find the plants measured. About twenty-five measurements were thus lost because the mistake was made of measuring the whole plant, which later was broken up by the winter rains and winds.

Number	September	May	Growth	Per cent. of growth
116	3.0 cm	4.1 cm	1.1 cm	36.66+
8218 A	34.0	38.0	4.0	11.76+
B	6.0	7.5	1.5	25.00
C	6.0	8.8	2.8	46.66+
96 A	28.0	32.5	4.5	16.07+
B	16.0	25.0	9.0	56.25
C	8.0	10.0	2.0	25.00
6418 A	46.0	54.0	8.0	17.00+
B	47.0	90.0	43.0	91.00+
6505 A	5.0	7.3	2.3	46.00
B	8.0	11.3	3.3	41.25
C	3.5	5.3	1.8	51.42+

Dismissing no. 6418 B, which may be due to the tearing of the long thallus by the winds, we see that the short lobes, 3 to 16 cm in length, show a rate of growth astonishing for lichens; but one to be expected where they grow under such favorable conditions. Taking those fronds of 16 cm or less in length, we find an average growth in length of 41 per cent. No measurements were made to ascertain the increase in width of the lobes.

It was intended to make an extended series of measurements on various lichens, but it was not possible to do so. However, measurements were made of a specimen of *Parmelia caperata* (L.) Ach. growing on the trunk of *Aesculus californicus*.

No. 5888	September 25	May 5	Growth
Longitudinal diameter	22.5 cm	24 cm	1.5 cm
Transverse diameter	21.0	22	1.0

The growth of this plant is really much greater than appears, as it is diffused over the entire margin of the circular thallus, and hence is difficult to express in percentages.

It is hoped that students in favorable localities may be induced by the above notes to undertake a series of measurements and observations on not only the very large foliaceous lichens, but also on the crustaceous lichens, many of which no doubt grow very rapidly.—ALBERT C. HERRE, *Stanford University, California.*

CURRENT LITERATURE.

BOOK REVIEWS.

Flowering plants and ferns.[1]

MR. J. C. WILLIS has done a wise thing in organizing his manual in a single volume. It is a book of general reference for those interested in learning something of the plants they meet in a botanical garden or museum, or in the field. In this edition much new material has been incorporated, especially in connection with those subjects that have had large recent development. The range of subjects covered is extraordinary, for the book gives the outlines of morphology, physiology, ecology, classification, geographical distribution, and the economic uses of vascular plants, besides containing "a dictionary in which the whole of the families and the important genera of flowering plants and ferns are dealt with."

It would seem impossible for one man to present such a range of subjects with any uniformity. He is almost sure to enlarge those he knows best at the expense of those with which he is the least familiar. For example, in this volume, while the older morphology with its copious terminology has full swing, the modern morphology has a scant showing and is presented in such a way as to bring no clear conception to the uninstructed. The alternation of generations and the various important evolutionary lines can be apprehended clearly only as they are approached by way of the lower plants. We have never seen any special gain in including these subjects in a book for the general reader dealing only with the vascular plants. If the statements are understood, they are not exact; and if they are exact, they cannot be understood.

These subjects, however, are very minor matters in the book, while the treatment of geographical distribution, forms of vegetation, and plant associations is extended and full of information. Mr. Willis seems to be more than anything else an ecologist, and his contact with various plant conditions has been unusual. As a consequence, this part of this book has all the flavor of personal experience.

The larger part of the volume is devoted to the presentation of the "classes, cohorts, orders, and chief genera," and is unique in the alphabetical arrangement and in the amount and kind of information one can find about plants concerning which he may be curious.

The book will certainly be of great use as a reference book in providing that kind of information for which it really stands, and the only adverse criticism is directed against its claim to include great regions of botany for which it does not stand.—J. M. C..

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[1] WILLIS, J. C., A manual and dictionary of the flowering plants and ferns. Second edition, revised and rearranged in one volume. Cambridge Biological Series. Pp. xii + 670. Cambridge: The University Press. 1904.

Vegetation of the Sihl valley.

A PORTION of the Sihl valley about 8^{km} south of Lake Zürich, Switzerland, is soon to be converted into a reservoir which will have an area of about 12$^{sq\,km}$. This valley is celebrated botanically as the home of a number of rare species, and presents ecological conditions which have caused many unique features in the vegetation, particularly those which make this one of the most southern localities for a truly boreal moor-formation. As the most peculiar portions of the present vegetation will be completely destroyed and the surrounding regions consideralby modified, an important service has been rendered to science by Dr. Max Düggeli in the presentation of a complete ecological and floristic study of the present vegetation.[2] The completeness and care with which this work has been done make adequate review difficult. Among the unique features of the vegetation is the conifer forest (*Picea excelsa*) in the lowlands at an elevation which is characterized everywhere else in Switzerland by deciduous forests. The deciduous forests occur at higher levels along the valley slopes where there is better insolation, better drainage, and consequently warmer soil.

The most widespread formation in the trough of the valley is the low moor (*Flachmoor*), while in several small areas the high moor or sphagnum bog (*Hochmoor*) occurs. Many samples of peat were examined and the vegetable remains identified. These showed that no essential change has taken place in the vegetation since the last retreat of the ice, though remains of several species were found which do not now occur in the valley. Everywhere the samples showed that the low moor (Carex, Phragmites, Equisetum, Hypnum, etc.) is the pioneer, followed by the high moor (Sphagnum and its companions). The same succession was found in the horizontal series. The author considers the most important factor in determining the occurrence of low moor and high moor to be the amount of dissolved salts in the water. He contrasts these formations as follows. The low moor develops where the water comes from the earth charged with considerable mineral matter. It is flat and centripetal. The high moor on the other hand grows only in soft water nearly free from minerals, is raised at the center, and is centrifugal in development. Not until a considerable thickness of peat has accumulated can the sphagnum get a start in the low moor. To test his hypothesis that the mineral content of the water conditions the occurrence of the high moor, he staked out squares of sphagnum 30^{cm} on a side, and watered daily with a liter of water containing minerals. Sphagnum watered thus with water from the Sihl river was killed in eleven days. Solutions of KNO_3, Na_3PO_4, $MgCO_3$, $CaCO_3$, etc., gave a similar result. His solutions do not appear to have been made up on a very scientific basis, and he makes no mention of a control in which sphagnum is similarly treated with a mineral-free water, but the results are suggestive.

[2] DUGGELI, MAX, Pflanzengeographische und wirtschaftliche Monographie des Sihltales bei Einsiedeln, von Roblesen bis Studen (Gebiet des projektierten Sihlsees). 8vo. pp. *222. pls. 4. figs. 10.* Zürich: Zürcher & Furrer. 1903.

The numerous types of meadows are treated in an interesting manner. Besides giving a complete description of each type with its various modifications, he contrasts meadows differing only in the direction of the slope, and others differing only in the character of the soil, thus showing the great ecological significance of these factors.

There are many commendable features about the work which will make it a suggestive model for future studies of similar small areas, not the least important of these being the lucid literary style.—G. H. SHULL.

NOTES FOR STUDENTS.

SHIBATA[1] proposes to designate as *amidases* certain enzymes found in the mycelium of *Aspergillus niger*, which spilt off ammonia from urea, biuret, and certain acid amides. They have nothing in common with the proteolytic enzymes. —C. R. B.

CHARLOTTE TERNETZ[2] finds in peat and peaty soils at least one fungus which is capable of fixing free N from the air. The fungus has a much branched septate mycelium and forms brown pycnidia which contain very small hyaline spores. It acts less energetically but more economically than *Clostridium Pasteurianum*.—C. R. B.

LIGNIER,[3] in an interesting comparison of the structures of Equisetales and Sphenophyllales, and of both with the structures of other pteridophytes, reaches the conclusion that these two groups, although differing in certain important particulars, really form one group, for which he proposes the name "Articulées." He further concludes that all the "Articulées" have a common ancestry, which was probably the most ancient Filicineae.—J. M. C.

LIGNIER[4] has discussed the nature of the so-called "flowers" of Gnetales in relation to similarly named structures in other gymnosperms and in angiosperms. He concludes that the staminate "flower" of Gnetales is a simple flower, and does not differ essentially from the much reduced flower of angiosperms; but that the ovulate "flower" is a very complex structure, really representing an inflorescence excessively reduced and condensed, and therefore could not be considered as a stage between the other gymnosperms and the angiosperms.—J. M. C.

IKENO, in reviewing and discussing the literature of the blepharoplast,[5]

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[1] SHIBATA, K., Über das Vorkommen von Amidespaltenden Enzymen bei Pilzen. Zeits. Ges. Biochemie **5**:384–394. 1904.

[2] TERNETZ, CHARLOTTE, Assimilation des atmosphärischen Stickstoffs durch ein torfbewohnenden Pilz. Ber. Deutsch. Bot. Gesells. **22**:267–274. 1904.

[3] LIGNIER, O., Equisétales et Sphénophyllales. Leur origine filicinéenne commune. Bull. Soc. Linn. Normandie V. **7**:93–137. 1903.

[4] LIGNIER, O., La fleur des Gnétacées est-elle intermédiaire entre celle des gymnospermes et celle des angiospermes? Bull. Soc. Linn. Normandie V. **7**:55–71. 1903.

[5] IKENO, S., Blepharoplasten im Pflanzenreich. Biol. Centrabl. **24**:211–221. *figs.* 3. 1904.

reasserts his previous view that the blepharoplast is a centrosome. He draws the following homologies between the structures concerned in plants (Characeae, Filicineae, and Equisetum) and animals (salamander and mouse): cilia are homologous with flagella; the thread from which the cilia are developed is homologous with the middle piece; and the deeply staining body in the plant spermatid (*Nebenkern* of Belajeff) is homologous with the deeply staining body (*Körperchen*) in the spermatid of animals.—CHARLES J. CHAMBERLAIN.

IN THE NUCLEI of the proembryo of *Ginkgo biloba*, according to ARNOLDI,[6] the chromatin is very inconspicuous, but increases in staining capacity and is easily seen during later stages in the development of the embryo. The staining reactions of the chromatin favor FISCHER'S theory that staining reactions are due to physical rather than to chemical causes. After the embryo has become somewhat elongated, it is differentiated into an upper haustorial region, a middle region, which is the suspensor, and an apical region which gives rise to the embryo proper.—CHARLES J. CHAMBERLAIN.

LAURENT[7] has published the results of a study of the Juncaceae, the first part dealing with the phenomena extending from the first appearance of the ovule to the formation of the testa, the second part describing the phenomena connected with seed germination. Various species of Juncus and Luzula were used. The facts of pollination and of fertilization are as usual; the undifferentiated embryos of certain species of Juncus are in contrast with the completely organized embryos of Luzula; the suspensor "contributes" to the formation of periblem and forms the root cap; the antipodal tissue, especially in Luzula, is noticeably active; and the structure of the testa forms the basis of a division of Luzula into two groups. —J. M. C.

SCHRÖDER CONTRIBUTES further data on the statocyst theory of geotropic perception.[8] He has investigated a considerable number of plants in which the occurrence of mobile starch has been hitherto questionable. In all cases when the parts were geotropically sensitive (he examined many species and various parts) he found starch-bearing cells which may be considered statocysts in HABERLANDT'S sense. A special study, also, was made of both stems and rhizoids of Chara. His results strengthen HABERLANDT'S view that the *Glanzkörper* at the apex of the rhizoids act as statoliths, but he could find no such bodies in the shoots. He leaves unsettled the question as to whether the oil drops in the sporangium of *Phycomyces nitens* act as inverse statocysts.—C. R. B.

[6] ARNOLDI, W., Beiträge zur Morphologie der Gymnospermen. VI. Ueber den Bau der Zellkerne im Embryo von *Ginkgo biloba*. VII. Die Embryobildung bei *Ginkgo biloba*. Ann. Inst. Agronomique et Forestière à Nowo-Alexandria **16**: 1–22. 1903.

[7] LAURENT, MARCELLIN, Recherches sur le développement des Joncées. Ann. Sci. Nat. Bot. VIII. **19**: 97–192. *pls.* 1–8. 1904.

[8] SCHRÖDER, H., Zur Statolithentheorie des Geotropismus. Beihefte Bot. Centralbl. **16**: 269–288. *pl. 13*. 1904.

GUILLIERMOND[9] has published a second paper upon nuclear and cell division in the ascus, extending his observations to *Pustularia vesiculosa*, *Peziza cotinus*, *Ascobolus marginatus*, and *Peziza rutilans*. For the first three he finds that the nuclear figures agree with what he and others have already described for other forms. *P. rutilans* possesses unusually large nuclei and differs from other forms so far studied in that the nuclear membrane disappears during mitosis; neither centrosomes nor asters are in evidence. In contradiction to DANGEARD'S generalization that the Ascomycetes have four chromosomes, GUILLIERMOND finds eight in *Aleuria cerea*, *P. vesiculosa*, and probably also in *Otidea onotica;* twelve in *P. cotinus*, and sixteen in *P. rutilans*.—W. G. MARQUETTE.

MOTTIER[10] has studied the development of the sperm in *Chara fragilis*, his account differing in certain important details from that of Belajeff. The blepharoplast is crescentic in cross-section, being concave within, and is of homogeneous structure, excepting a strip of granular substance along the concave side at the posterior end. It arises as a delicate thread-like differentiation of the cytoplasm at the surface of the cell, seeming to be a modification of the plasma-membrane, and in its later stages is one piece, extending the entire length of the sperm. The cilia were always found attached some distance back of the anterior extremity of the blepharoplast, and did not seem to develop from any centrosome-like body or "Plasmahöcker," as described by BELAJEFF, STRASBURGER, and others.—J. M. C.

PARTHENOGENESIS in *Taraxacum officinale* was reported about a year ago by RAUNKIAER,[11] but the evidence was hardly convincing. In a short preliminary announcement JUEL[12] describes the tetrad formation in the ovule. The embryo sac mother-cell divides, giving rise to two cells of unequal size. The smaller cell, which is nearer the micropyle, disorganizes without further division, while the larger cell develops at once into an apparently normal embryo sac. Although the number of chromosomes was not determined definitely, there seems to be no reduction, between 20 and 30 chromosomes appearing in both the embryo sac mother-cell and in vegetative cells. The mitosis in the embryo sac mother-cell is not heterotypic, although in some phases it resembles this form.—CHARLES J. CHAMBERLAIN.

PARTHENOGENESIS in *Thalictrum purpurascens* was described by OVERTON in 1902.[13] A preliminary announcement[14] of his further studies shows that the

[9] GUILLIERMOND, M. A., Recherches sur la karyokinese chez les Ascomycetes. Rev. Gén. Bot. **16**: 129–000. 1904.

[10] MOTTIER, D. M., The development of the spermatozoid in Chara. Annals of Botany **18**:245–254. *pl. 17*. 1904.

[11] See BOT. GAZ. **36**: 397. 1903.

[12] JUEL, H. O., Die Tetradenteilung in der Samenanlage von Taraxacum. Arkiv Bot. K. Svenska Vetensk. Akad. **2**:— (reprint pp. 9). 1904.

[13] BOT. GAZ. **33**:363–375. 1902.

[14] OVERTON, J. B., Ueber Parthenogenesis bei *Thalictrum purpurascens*. (Vorläufige Mitteilung.) Ber. Deutsch. Bot. Gesells. **22**: 274–283. *pl. 15*. 1904.

formation of the pollen is normal, a reduction in the number of chromosomes taking place in the pollen mother-cells. In the formation of the megaspore in some cases a tetrad of four megaspores is formed, accompanied by a reduction in the number of chromosomes. In other cases no reduction takes place in the megaspore mother-cells, and sometimes a true tetrad is not formed. Such conditions are not unexpected, since OVERTON had previously shown that while Thalictrum is often parthenogenetic fertilization may occur. The number of chromosomes in the sporophyte is twenty-four and in the gametophyte twelve. —CHARLES J. CHAMBERLAIN.

PARTHENOGENESIS in *Gnetum Ula* Brogn. is reported by LOTSY.[15] In the development of the female gametophyte, as in *G. Gnemon*, a period of free nuclear division is followed by a period of cell formation. The cells of the lower part of the gametophyte are small and form a close tissue, while in the upper part they are much larger and are loosely associated. No pollen tubes were observed, but many of the loose cells in the upper part of the gametophyte behaved like zygotes, sending out tubes as described for other species of Gnetum. The number of cells behaving in this way was so large that the pollen tubes could scarcely have been overlooked had they been present. This study has strengthened LOTSY in his previous view that the angiosperms have not come from the Gnetaceae.—CHARLES J. CHAMBERLAIN.

CARLETON[16] has published a series of notes giving the results of investigations and culture experiments with rusts. It is found that *Uromy es euphorbiae* can be propagated through the agency of seeds and seed pods infected with the fungus. This is the first instance of a rust propagated in this manner. A long series of experiments with the black stem rust of Agropyron and Elymus showed that this rust could be transferred to a number of hosts, including wheat, barley, *Hordeum jubatum*, *Agropyron tenerum*, *A. Richardsoni*, *Elymus canadensis;* while the orange leaf rust of the same species is sharply limited in its host plants. The fact mentioned by the writer in a former paper, that the uredo of the orange leaf rust is hardy during the winter, is again emphasized in this discussion. It is also shown that the uredo of blue grass rust is hardy.—H. HASSELBRING.

THE FACT that copper sulfate is much more toxic in its effect upon plants than upon animals is taken advantage of by MOORE and KELLERMAN[17] in a method for killing algae, etc., in reservoirs, without at the the same time rendering the water injurious for human consumption. According to the organisms to be exterminated, to the flow of the water, and other conditions, a certain amount of the poison is added to the reservoir, a device being used to insure uniform

[15] LOTSY, J. P., Parthenogenesis bei *Gnetum Ula* Brogn. Flora **92**: 397–404. *pls. 9–10.* 1903.

[16] CARLETON, M. A., Investigations of rusts. U. S. Dept. of Argic. Bur. Pl. Indus. Bull. 63. pp. 29. *pls. 2.* 1904.

[17] MOORE, G. T., and KELLERMAN, K. F., A method of destroying or preventing the growth of algae and certain pathogenic bacteria in water supplies. U. S. Dept. of Agric. Bur. Pl. Indus. Bull. 64. pp. 44. 1904.

distribution of the salt. The amount of copper salt needed will never exceed one part in a million of water, and since copper is not poisonous to human beings in doses of less than perhaps 0.02^{gm} daily, it appears that some fifty quarts of treated water might be taken daily with impunity! The paper represents what seems to the reviewer to be a most excellent piece of work.—B. E. LIVINGSTON.

ROLFS[18] has described several diseases of citrous trees and fruits due to *Colletotrichum gloeosporioides*. When the fungus attacks the young growing twigs, into which it gains entrance through the leaves, it produces a disease known as "wither-tip," characterized by the dying back of the young branches. The most serious damage is caused to the mature fruit into which the fungus gains entrance through an injury or bruise. The fungus rapidly develops until the whole rind is brown. This injury occurs to a large extent during the handling of the fruit, especially in the coloring process. All varieties of citrous fruits are attacked by the fungus. Spraying with potassium sulfid and copper mixtures are suggested as remedies, although no experimental data are given. Cultivation, fertilization, and pruning are also suggested as preventive measures. — H. HASSELBRING.

A RECENT CONTRIBUTION[19] from the Gray Herbarium contains six papers by the various members of the herbarium staff. The first three, by B. L. ROBINSON and J. M. GREENMAN, are "Revision of the genus Sabazia," chiefly Mexican in distribution and containing 6 species; "Revision of the Mexican and Central American species of Trixis," 16 species being presented, 6 of which are new; and "Revision of the Mexican and Central American species of Hieracium," 5 of the 19 species being new. The two papers by M. L. FERNALD are "Synopsis of the Mexican and Central American species of Alnus," one of the six species being new; and "Some new species of Mexican and Nicaraguan dicotyledons," 13 being described. A paper by J. M. GREENMAN, entitled "Diagnoses and synonymy of Mexican and Central American spermatophytes," includes descriptions of 39 new species, besides new varieties and discussions of certain critical species.—J. M. C.

HYBRIDS between Fundulus and Menedia have been investigated by MOENKHAUS.[20] The fertilized eggs begin to develop normally, but abnormalities soon appear and the embryos do not develop beyond the closure of the blastopore. Botanists will be interested in the history of the chromatin. The chromosomes of Fundulus are rather long and straight, while those of Menedia are shorter

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[18] ROLFS, P. H., Wither tip and other diseases of citrous trees and fruits caused by *Colletotrichum gloeosporioides*. Bur. Pl. Industry, Bull. 52. pp. 20. *pls.* 6. 1904.

[19] Contributions from the Gray Herbarium of Harvard University. N. S. no. XXVIII. Proc. Amer. Acad. Sci. **40**: 1–57. 1904.

[20] MOENKHAUS, W. J., The development of the hybrids between *Fundulus heteroclitus* and *Menedia notata* with especial reference to the behavior of the maternal and paternal chromatin. Amer. Jour. Anat. **3**: 29–65. *pls.* 1–4. 1904.

and are usually curved; consequently it is possible to distinguish the paternal and maternal chromosomes during fertilization and during mitosis. At the first two mitoses in the fertilized egg the two chromatins appear grouped and bilaterally arranged on the spindle, but later the grouping disappears. There is a mingling of chromatin in the resting nuclei, but the characteristic chromosomes of the two parents can be distinguished during mitosis. The writer strongly supports the theory that the chromosome is a permanent organ of the cell.—CHARLES J. CHAMBERLAIN.

THE THEORY of the individuality of the chromosome is supported in a recent paper by ROSENBERG,[21] whose work on Drosera has already furnished considerable evidence in favor of this view. In the resting nuclei of Capsella, particularly in the nuclei of the cells of the suspensor, the 32 chromosomes characteristic of the species can be counted without difficulty. The same number was counted in the sporophytic mitoses, and 16 were counted in the pollen mother-cells and in the embryo sac. Further, 48 were found in mitosis in the endosperm. Mitoses in Zostera show 6 chromosomes in pollen mother-cells and 12 in root tips. Resting nuclei in the seed coat showed 12 chromosomes. Resting nuclei in the integument of Calendula showed about 30 chromosomes, while mitoses showed 32 in the sporophyte and 16 in the gametophyte. The forms mentioned have short thick chromosomes, which are more easily traced into the resting condition of the nucleus than are the long filamentous chromosomes of the Fritillaria type. —CHARLES J. CHAMBERLAIN.

LEAVITT[22] has published the results of an extensive study of root hairs. Two types are recognized. In one case any cell of the piliferous layer in the young fixed tissue may produce a hair, there being no specialization for this purpose. This type is characteristic of most Filices, of some monocotyledons, and of the dicotyledons. In the other case special cells for producing hairs are cut off in the very young piliferous layer by a peculiarly oriented cell-division. These specialized cells the author calls "trichoblasts," and they are characteristic of all pteridophytes except most Filices, of most monocotyledons, and of the Nymphaeaceae among the dicotyledons. Attention is also called to the relationship in origin, form, and probable function between the trichoblasts and the so-called "transfusion cells" of the hypodermal layer, the short roundish or oval cells that alternate in each longitudinal row with the elongated prismatic ones. It is singular that among other references to literature the author has not included his own paper[23] of two years ago, in which the trichoblasts of Azolla were fully described. —J. M. C.

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[21] ROSENBERG, O., Ueber die Individualität der Chromosomen im Pflanzenreich, Flora **93**: 251–259. *figs.* 7. 1904.

[22] LEAVITT, R. G., Trichomes of the root in vascular cryptogams and angiosperms. Proc. Boston Soc. Nat. Hist. **31**: 273–313. *pls. 16–19.* 1904.

[23] The root hairs, cap, and sheath of Azolla. BOT. GAZ. **34**: 414–419. *pl. 16.* 1902.

THE FORMATION of the heterotypic chromosome is described in a recent article by BERGHS.[24] Although referring often to a "longitudinal division" of the spirem, the writer wishes it understood that he means merely the appearance throughout the length of the spirem of two filaments more or less parallel. Whether the two filaments result from the splitting of a single filament or whether there is simply the reappearance of two distinct filaments will be discussed in a future paper. The split which appears in the spirem is the one which separates the two filaments entangled in the strepsinema stage. The spirem passes into the strepsinema stage by a longitudinal fission, not by looping and approximation, as DIXON claims. After the strepsinema stage, the chromosomes are completed by a thickening and shortening. The two pieces, which the heterotypic mitosis separates, are the two longitudinal pieces of the spirem thread. If there is an approximation, it must be looked for during the formation of the spirem. This latter point will be discussed in a forthcoming paper.—CHARLES J. CHAMBERLAIN.

ROSENBERG,[25] in continuing his studies upon *Drosera rotundifolia*, describes the two mitoses in the pollen mother-cells and arrives at some interesting conclusions. In an early prophase of the first division, before the disappearance of the nuclear membrane, the chromosomes appear in pairs, which soon unite to form double chromosomes. There are 20 such double chromosomes, and they are formed by the uniting of the 40 chromosomes of the vegetative mitoses. In a series of diagrams the paternal and maternal chromosomes are represented first as distinct, and soon after as approximated in pairs. Each paternal and maternal chromosome now divides, and all of the paternal chromosomes pass to one pole and all of the maternal to the other pole. The second mitosis simply separates the two parts of each chromosome, which was already formed during the prophase of the first division, so that in two of the four pollen grains all of the chromosomes are paternal and in the other two, all are maternal. The suggestion is made that the double thread of the early spirem is due to fusion rather than to splitting, and is consequently a process of reduction.—CHARLES J. CHAMBERLAIN.

TWO PAPERS from the University of St. Petersburg bear upon the rôle of enzymes in respiration. Both are based upon quantitative work.

KOSTYTSCHEW[26] experimented with *Mucor stolonifer* and *Aspergillus niger*.

[24] BERGHS, JULES, La formation des chromosomes heterotypiques dans la chromosome végétale. I. Depuis le spirème jusqu'aux chromosomes mûrs dans la microsporogénèse d' *Allium fistulosum* et de *Lilium lancifolium* (*speciosum*). Le Cellule **21**: 173–189. *fig. 15*. 1904.

[25] ROSENBERG, O., Ueber die Reduktionsteilung im Drosera. Meddel. Stockholms Högs. Bot. Inst. pp. 13. *figs. 20*. (Reprint signed April 1904, but the volume and date of the publication in which the article appeared are not indicated.)

[26] KOSTYTSCHEW, S., Über Atmungsenzyme der Schimmelpilze. Ber. Deutsch. Bot. Gesells. **22**: 207–215. 1904.

His most important conclusions are that both the absorption of oxygen and the excretion of carbon dioxid in the respiratory process are at least partially effected by the activity of specific enzymes; and that the excretion of carbon dioxid when free oxygen is excluded is occasioned by the activity of an enzyme which is not identical with the zymase of BUCHNER.

MAXIMOW[27] studied the behavior of the liquor expressed from the mycelium of *Aspergillus niger*, and obtained the important result that this liquor on standing exhibits a gas metabolism analogous to respiration. This exchange of gases occurs as a consequence of the activity of enzymes present in the liquor. The excretion of carbon dioxid is accomplished by an enzyme analogous to zymase, while the absorption of oxygen is induced by one of the oxydases. The former enzyme analogous to zymase also resembles zymase in being equally active in air or in hydrogen.—R. H. POND.

SABLINE[28] subjected roots of *Vicia Faba* to different temperatures; to lack of oxygen; to the action of saccharose, distilled water, sulfuric ether, quinin sulfate, and lithium chlorid, in order to determine the effect of various conditions on karyokinesis. Few divisions were found in roots subjected to 0° C. The linin was coarse-meshed and the chromatin stained blue. At 10° growth was slow and chromosomes blue. At 30°, the optimum temperature, the nucleoli did not wholly disappear in some instances, and the chromosomes stained blue; when the nucleoli disappeared the chromosomes stained red. After deprivation of oxygen chromosomes stained red. When subjected to saccharose the chromosomes were very large and stained red, and nucleoli were enormous. There were no mitoses in cells placed in distilled water. Amitosis was frequent in nuclei subjected to the action of sulfuric ether. In nuclei which divided mitotically the chromosomes were frequently scattered, and in some cells stained red, in others blue. Amitotic division was sometimes found in cells acted on by quinine sulfate. Multipolar spindles were frequent. Lithium chlorid caused the chromosomes to become abnormally large and the stain was red.—W. J. G. LAND.

A PAPER from Pfeffer's laboratory by WIEDERSHEIM[29] contributes new data to the physiology of photonastic and thermonastic movements. The opinion of JOST and SCHWENDENER that only the primary movement in response is a direct result of external stimulation, while the secondary movement constituting a correction of the primary movement is autotropic, is not supported. The view of PFEFFER that the secondary movement is not autotropic but is directly induced by the same stimulus which causes the primary movement, is strongly supported. The prophecy of FITTING that the "double curve" expressing the twice accel-

[27] MAXIMOW, N. A., Zur Frage über die Atmung. (Vorläufige Mitteilung). Ber Deutsch. Bot. Gesells. **22**: 225–235. *fig. 1.* 1904.

[28] SABLINE, V., L'influence des agents externes sur la division des noyaux dans les racines de *Vicia Faba*. Rev. Gén. Bot. **15**: 481–497. *pls. 15, 16.* 1903.

[29] WIEDERSHEIM, W., Studien über photonastische und thermonastische Bewegungen. Jahrb. Wiss. Bot. **40**: 230–278. *figs. 20.* 1904.

erated growth of the "middle zone" which was found by him to characterize the haptotropic movements of tendrils could also be demonstrated for photonastic and thermonastic movements is entirely fulfilled. FISCHER's assignment of *Impatiens parviflora* to the group of autonyctitropic plants is ratified. The plants best suited for investigation of photonastic movements were found to be *Impatiens parviflora*, *I. glanduligera*, and *Chenopodium album;* while *Tulipa Duc van Toll* and *Crocus luteus* are excellent for study of thermonastic movements. The conclusions are based upon data obtained by the quantitative methods which characterize the laboratory in which the investigation was made.—RAYMOND H. POND.

A SUGGESTION as to the formation of asparagin is advanced by PRIANISCHNIKOW[30] in a preliminary paper. He argues that as the decomposition of proteids tends to produce ammonia on the one hand, and amidoacids (perhaps even aspartic acid) on the other, asparagin may be produced by the formation of ammonium aspartate from which a molecule of water separates. This secondary origin of asparagin rather than its origination as a direct decomposition product of proteids he infers from the following facts.

He and others have found that the relative amounts of asparagin and aspartic acid produced in germination and by hydrolysis of proteids are quite unlike, and they are the more unlike the later the stage of germination. In late stages the rate of asparagin production even surpasses that of proteid decomposition. Further it has been found that the decomposition of proteids by proteolytic enzymes (such as occur in the germinating seeds) gives rise to the same amidoacids and bases as hydrolysis with mineral acids, but no asparagin is formed. Finally, the distribution of asparagin in the cotyledons and growing regions is not such as would occur were it produced for migration out of the stored proteids in the cotyledons, since it is much more abundant in the growing parts than in the cotyledons.—C. R. B.

GATIN[31] has been investigating the development of the first root in the germination of *Archontophoenix Alexandrae* and *Phoenix canariensis*. The first mentioned follows the "admotiva" mode of germination in which the hypocotyl scarcely elongates. *P. canariensis* follows the "remotiva" method, the hypocotyl elongating for the supposed purpose of burying the young plant. The mature embryo of *A. Alexandrae* possesses a root of which a rudimentary vascular axis only is present. The cortex arises during germination from a zone surrounding the tip of this axis and forming apparently an integral part of the cotyledonary tissue. The region lying directly in the path of growth of the vascular axis is distinguishable into three parts. The innermost, lying directly in contact with the end of the axis, forms the root-cap. The next, together with the adjacent

[30] PRIANISCHNIKOW, D., Zur Frage der Asparaginbildung. (Vorläufige Mitteilung.) Ber. Deutsch. Bot. Gesells. **22**: 35–43. 1904.

[31] GATIN, C. L., Observations sur la germination et la formation de la première racine de quelques palmiers. Rev. Gén. Bot. **16**: 177–187. *figs.* 7. 1904.

epidermis, which forms the outermost, enters into the formation of a root sheath. The first root forms an angle of about 90° with the axis of the shoot. A subsequently formed adventitious root, which continues the shoot axis, exceeds the primary in growth and becomes the principal root at least for a time. The origin of cortex, cap, and sheath in *P. canariensis* is the same as in *A. Alexandrae*, but the axis of the primary root coincides with that of the shoot, so that the first root remains the principal one.—F. H. Billings.

Gerassimow[32] has investigated the influence of the nucleus on the growth of the cell. By exposing various species of Spirogyra with cells in the process of division for one-half an hour to one hour to a temperature a little above 0° C., he was able so to interfere with the processes of mitosis that the following irregularities arose when the filaments were transferred and cultivated under normal conditions: cells with a single large nucleus, the equivalent of two normal nuclei; cells with the daughter nuclei fused to a greater or less extent, giving one the impression of amitosis; cells in which the daughter nuclei are normally formed but lie close to one another and both on the same side of the newly formed cell wall. This wall is either complete, thus cutting off a cell without a nucleus, or a small opening remains forming a non-nucleate chamber communicating with a binucleate cell. From a large number of measurements made upon cells as above described the author draws the following conclusions: the growth of the cells having an excess of nuclear material is greater than the average growth of normal cells; the non-nucleate cells are short-lived and the growth is very slight; the non-nucleate chambers are longer-lived and grow more than the non-nucleate cells; the cells having an excess of nuclear material may conjugate either with normal cells or with cells similar to themselves.—C. F. Hottes.

Zimmermann[33] has described the most important insects and fungous enemies of the coffee plant in the Island of Java. The following are noted here for reference. A sort of stigmonose is produced by punctures of *Pentatoma plebeja*, which attacks the lower side of the leaves and young stems. The author was unable to observe any detrimental effect on the plant due to punctures on the leaves. Very young shoots, however, wither as a result of the insect punctures. The histological characteristics of the punctures are described in detail. Of the fungi described, the well-known *Hemileia vastatrix*, occurring everywhere on the island each season, causes the greatest loss. This rust fungus is often accompanied by other parasites, as *Glocosporium coffeanum* Del., *Coniothyrium coffeae* Zimm., *Colletotrichum incarnatum* Zimm., and *Cercospora coffeicola* Berk. & Cooke. *Capnodium javanicum*, *Rhombostilbella rosea*, and *Antennaria setosa* are described as new species growing on the surface of the leaves in secretions of *Lecanium viride* and other insects. A fungus whose systematic position is not

[32] Gerassimow, J. J., Zur Physiologie der Zelle. Bull. Soc. Imp. Nat. Moscow, no. 1, pp. 134. *pl. 1.* tables 60. 1904.

[33] Zimmermann, A., Einige pathologische en physiologische Waarnemingen over Koffie. Mededel. 's Lands Plantentuin, no. 67. pp. 105. *pls. 4.* 1904.

certain causes an injury termed "spiderweb disease." A number of other fungi, many of them new, are described on the stems, roots, and fruit of the plant. Those on the fruit are mostly saprophytic molds. The last part of the report contains some observations on sterility of coffee flowers, variation in the fruit, polyembryony and the influence of light, and injuries due to nematodes.—H. HASSELBRING.

THE INFLUENCE of chloral hydrate upon nuclear and cell division is described in a recent paper by NĚMEC.[34] It is possible that very weak solutions may stimulate division, but more concentrated solutions cause various disturbances. Some stages in mitosis are more readily and more profoundly influenced than others. The phragmoplast is most resistant. The stages of metakinesis are much less resistant, and the equatorial plate stages and stages in the formation of the spindle are the most sensitive of all. Root tips which have been treated for an hour in 0.75 per cent. chloral hydrate show a degeneration of the spindle fibers and an interruption of mitosis. If the solution be washed out and normal conditions restored, mitosis proceeds in the usual manner, but the interrupted mitoses give rise to cells with several nuclei, or an irregular nucleus and incomplete walls may be formed. In binucleate cells the nuclei may fuse, and the nucleus resulting from such a fusion has double the usual number of chromosomes. In cells in which the two nuclei do not fuse, two mitoses may occur simultaneously. Cells without nuclei may be formed. Mitoses with double the number of chromosomes gradually disappear from the root tip and apparently a reduction in the number of chromosomes takes place. There was no conclusive evidence that chloral hydrate causes amitosis. Figures which might be mistaken for amitosis were abundant, but they could be interpreted as interrupted or modified mitoses. —CHARLES J. CHAMBERLAIN.

NON-SEXUAL NUCLEAR FUSIONS is the title of a series of short papers by NEMEC.[35] Much of the material was obtained by treating root tips of seedlings of *Pisum sativum* with a 0.75 per cent. solution of chloral hydrate. Tips 3 to 3.5^{cm} long were placed about 2^{cm} deep in the solution and allowed to remain for an hour. They were then washed in water, material being fixed at intervals. Material fixed immediately after removal from the chloral solution shows numerous binucleate cells besides other abnormalities. After an hour's washing in water normal mitosis and abnormalities become less numerous, and after about twenty-eight hours' washing the processes are practically normal. The nuclei of the binucleate cells fuse and some stages in the fusion might be mistaken for amitosis. No amitosis, however, was observed. When a nucleus which has resulted from fusion divides, it shows double the number of chromosomes characteristic of the sporophytic cells. NĚMEC believes that the double number is not maintained

[34] NĚMEC, B., Ueber die Einwirkung des Chloralhydrats auf die Kern und Zellteilung. Jarhb. Wiss. Bot. **39**: 645–730. *figs. 157*. 1904.

[35] NĚMEC, B., Ueber ungeschlechtliche Kernverschmelzungen. Sitz. Ber. Königl. Böhm. Gesells. Wiss. I, 1902; II, July 1903; III, Nov. 1903.

but soon becomes reduced. The fusions resemble sexual fusions in the behavior of the chromatin. The nuclear fusion and the reduction may be regarded as automatically regulated phenomena. Reduction may sometimes be an atavistic character; it is a result of fusion rather than a preparation for it. Morphologically the most important character of fertilization lies not in nuclear fusion but in cell fusion. When the conditions for cell fusion are present the other phenomena (under certain conditions) follow necessarily as automatically regulated processes.—CHARLES J. CHAMBERLAIN.

THE EXTANT theories of causality in leaf arrangement have been critically discussed in detail by WINKLER[36] in two parts of a paper on this subject, of which we are promised a continuation in a third part. The author brings forward evidence from various plants that the mechanical theory of SCHWENDENER will not suffice to explain the formation and development of primordia. There appear to be many cases in which the primordia are not constant in size at the start, many in which contact or absence of contact between different primordia plays no controlling rôle in development, and also many in which pressure of older parts has no influence. The various theories of teleological nature, such as the common one which attributes leaf arrangement to the need of having these organs so placed as to give best access of air and light, are discussed rather more fully than would seem necessary for intelligent readers. It is to be hoped that such theories may at length be accorded a decent burial and then allowed to rest.

The constructive part of this paper points out that any theory of leaf arrangement which is satisfactory must consider internal factors together with the external ones. WINKLER is careful to indicate that by this term he refers merely to those protoplasmic conditions (probably purely physical) of which we know absolutely nothing at present except that they exist. The general conclusion of the paper may be summed up in a paraphrase of the author's words, that the formation of organs at the growing tip is an extraordinarily complex process controlled by a whole series of factors of different kinds, concerning the nature and influence of which we know practically nothing.—B. E. LIVINGSTON.

SWINGLE[37] has just published the results of his study of the date palm, and they are important not only in demonstrating the possibilities of a valuable crop for the United States in regions otherwise apparently hopeless from an agricultural point of view, but also from their much larger practical bearing upon the value of such investigations. The following statement is vigorous, but who will dispute it? "At present it is no exaggeration to state that the life history requirements and the limits of the power to resist unfavorable environmental conditions are far better known for many microscopic lower plants, such as bacteria, fungi, and algae, even for species having no economic importance, than for the most

[36] WINKLER, H., Untersuchungen zur Theorie der Blattstellungen. I. Jahrb. Wiss. Bot. **36** : 1–79. *pls. 4.* 1901; II, *ibid.* 501–544. *pl. 1.* 1903.

[37] SWINGLE, W. T., The date palm and its utilization in the southwestern states, pp. 155. *pls. 22.* Bur. Pl. Industry, U. S. Dept. Agric., Bulletin 53., April 28. 1904.

important crop plants whose culture provides employment for tens of millions, and whose products constitute the daily food of hundreds of millions of human beings. Such a condition is discreditable alike to biological and to agricultural science and should not longer continue."

In reference to the date palm the following conclusions are reached: It can endure any degree of heat and any amount of dryness in the air, and is even favored by hot winds and by a rainless summer. The best sorts can mature only in regions having a very long and very hot growing season. It can endure more alkali in the soil than any other profitable crop plant, and can thrive on soils containing from 0.5 to 1 per cent. of alkali, even when irrigated with brackish water containing 0.43 per cent. (430 parts per 100,000) or more of injurious alkali. It can withstand without injury accumulations of alkali at the surface of the soil that would kill all other crop plants, even those considered to be very resistant to alkali.—J. M. C.

PORSILD[38] gives an account of the expedition to Disko Island in 1898. The account includes observations on the geology and topography of the island, incidental notes on the fauna, and detailed notes on the flora. In conclusion he discusses the southern flora of the island, considering the questions of possible relict endemism from a warmer epoch, and migration in postglacial times.

The upland vegetation consists of lichens and herbaceous plants with very few shrubs. Under this category are placed the windy plateaus, the sheltered terraces of the trap, the gravelly bottoms and deltas, and the raised sea bottoms. The Calluna heath is found on the talus and gradual slopes of the trap, on large hills poor in humus, or in depressions rich in water. The tundra is discussed as a peculiar formation transitional between the moss-bog and the Calluna heath, the transition to one or the other depending upon the water content of the soil. Moss bogs are found where water stagnates and is sour, on gneiss, on uneven basalt, and on undrained terraces, where the bog often goes above the Calluna. In some cases the moss formation actually forms the climax type after the Calluna, and in comparison is relatively unmixed in its species.

Halophytes occur along the sea strand. Cyperaceous meadows occur only along streams in very flat and moist soil. Dwarf birches and willows are also found along streams, the former occurring on a somewhat drier soil than the latter.

As regards vegetation in the inland waters, lakes are poor in species, but rich in individuals. Glacial streams contain no vegetation or at most only a few diatoms. Other streams, especially the warm ones, are rich in algae, especially *Hydrurus foetidus*. The floristic difference on gneiss and basalt is not marked when flowering plants are considered. Mosses, on the other hand, decidedly prefer the one or the other. Thus species of *Andreaea*, *Sphagnum*, and *Sarcos-*

[38] PORSILD, M. P., Bidrag til en Skildring af Vegetationen paa Oen Disko tilligemed spredte topografiske og zoologiske Iagttagelser. Meddel. om Grönland **25**: 91–308. *pls. 1–6.* 1902.

cyphus never occur on basalt or tuff, while *Drepanium, Thuidium abietinum, Brachythecium salebrosum*, and *Pottia latifolia* are characteristic basalt plants. —G. H. JENSEN.

IN A RATHER lengthy paper on embryonal substance, NOLL[39] discusses the various theories which have been announced regarding the controlling force in development, and presents some interesting observations on the protoplasm of the growing tip in Bryopsis, together with his interpretation of the latter. The facts, determined by very careful observation of the growing tips, are as follows: The protoplasmic circulation of the filament occurs throughout the whole plant, extending into the tip region as well as elsewhere; nevertheless the protoplasm of the apical portion is very different from that below. While the non-growing portions have only the usual thin protoplasmic layer lining the wall, that of the growing tip occupies the whole lumen. Also in the tip there are no chloroplasts, and the protoplasm is much more dense than elsewhere, while the nuclei are more numerous. Since the currents of cyclosis are constantly carrying new substance into the tip and out again, there is a constant transformation of protoplasm at the limit of the denser region from somatic to meristematic and *vice versa*. At this limit the entering substance becomes more dense and the chloroplasts are left behind in apparently somewhat the same way as lighter bodies float upon water. NOLL suggests that the increase in density may be due to loss of water from the entering protoplasm. (It occurs to the reviewer that it may be due to incipient coagulation of the colloidal bodies.)

On account of this constant interchange between apical and more basal portions, it is impossible to suppose here that the meristematic protoplasm in the former region is fundamentally different from the somatic. The author concludes that, since the *Hautschicht* is the only part of the living substance which is constantly at the tip, and does not take part in the cyclosis, it must be in this that the controlling factor of growth is located. Thus he looks upon the *Hautschicht* of the tip as the only true embryonal substance here, and it does not contain nuclei. Therefore, he points out that in Bryopsis the factor producing growth does not lie in nuclei. The objection to this conclusion lies in the fact that we cannot be sure that some form of cyclosis does not occur in the *Hautschicht;* that it is not observed does not prove its absence.—B. E. LIVINGSTON.

SPERMATOGENESIS in *Marchantia polymorpha* has been reinvestigated by IKENO.[40] In many points this investigation has confirmed the earlier work of STRASBURGER and SCHOTTLÄNDER, but the more critical methods have made it possible to bring out important features which have hitherto been overlooked. During the early divisions in the young antheridium no nucleolus is demonstrated; the number of chromosomes is eight, as SCHOTTLÄNDER has already shown.

[39] NOLL, F., Beobachtungen und Betrachtungen über embryonale Substanz. Biol. Centralbl. **23**: 281–297, 321–337, 401–427. 1903.

[40] IKENO, S., Die Spermatogenesis von *Marchantia polymorpha*. Beih. Bot. Centralbl. **15**:65–88. *pl.* 3. 1903.

SCHOTTLÄNDER'S statement that centrosomes are present during the diaster and dispirem stages in young antheridia is also confirmed. Centrosomes were found throughout the spermatogenous divisions, during which they perform the ordinary functions of centrosomes. They do not persist throughout the life history of the cell, but appear at the beginning of each mitosis and disappear by the time the dispirem stage is reached. After the spermatogenous divisions have ceased, the centrosome reappears, functioning not as a centrosome but as a blepharoplast giving rise to the cilia. IKENO interprets as genuine centrosomes the blepharoplasts of various pteridophytes and of the cycads and Ginkgo.

According to current accounts, the spermatogenous tissue, at the close of the spermatogenous divisions, consists of approximately cubical sperm mother-cells, each of which gives rise to a single spermatozoid. The present investigation shows that there is still another nuclear division in a diagonal plane and not followed by the formation of a cell wall, so that each sperm mother-cell gives rise to two spermatozoids. This is true not only for Marchantia, but probably for other liverworts also. At this diagonal division, the centrosomes, after functioning as centrosomes, do not disappear, but persist and function as blepharoplasts. The blepharoplast elongates, and its body comes into close contact with the inner surface of the spermatid cell, so that it appears like a thickening of the *Hautschicht*. From this elongated centrosome, or blepharoplast, come the two cilia.

Shortly after the diagonal division a peculiar spherical body, staining somewhat like the centrosome, appears in each spermatid mother-cell, but is readily distinguished from the centrosome by its larger size and its position. It is still distinguishable after the centrosome has given rise to the cilia. From the resemblance to the chromatoid body of some animals, the same name is suggested for this body. Occasionally each of the cells resulting from the diagonal division divides. Such a division is accompanied by a division of the chromatoid body and of the centrosome. Thus four spermatozoids would be formed from what is usually denominated a sperm mother-cell. However, only two spermatozoids mature, the supernumerary ones being used for nutrition. This homology of the centrosome is fully discussed.—C. J. CHAMBERLAIN.

PROBLEMS CONCERNING WATER ABSORPTION by epiphytic Bromeliaceae have been investigated by MEZ,[41] who has gone carefully over the ground traversed a few years ago by SCHIMPER. He agrees with SCHIMPER in most particulars, but is at variance with him regarding the behavior of the individual scale during water absorption. SCHIMPER claimed that the four central and empty cells of the shield part of the scale are filled with air when the surface of the plant is dry, and that the air is replaced by water when the surface is wet. MEZ by microchemical tests, as well as by direct observation, finds that the cavities of

[41] MEZ, CARL, Physiologische Bromliaceen-Studien. I. Die Wasser-Oekonomie der extrematmosphærischen Tillandsien. Jahrb. Wiss. Bot. **40**: 157–229. *figs.* 26. 1904.

the four cells are always free from air, so that when dry conditions prevail they are in a state of complete collapse. The much thickened upper surface of the shield part, or *Deckel*, is the active part concerned in absorption of water from the capillary spaces beneath the scale. It is composed of a mesh of cellulose containing large deposits of pectin. A layer of pure cellulose covers all. When wet, this *Deckel* absorbs water rapidly, and being resisted beneath by the epidermis, as well as on the sides by the cellulose wing of the scale, the only direction in which swelling can take place is upwards. As a consequence, the *Deckel* becomes convex, the cone-like processes on its under side straighten out and become more obtuse, with the result that the collapsed walls of the four cells separate, causing cavities into which water is drawn through thin areas in their outer walls, in response to the negative pressure. Water is thus absorbed till the scale is distended to its greatest extent, and the four central cells are filled with water. MEZ has calculated the amount thus drawn into one scale in *Tillandsia streptocarpa*, and found it to be approximately $0.000464^{cu\,mm}$ or 1.451^{cc} for a given entire plant having 1,880,000 scales. The shield, or central region of the scale, lies in connection with a row of 1–4 living cells, which in part form the stalk of the scale. The uppermost of these is larger than the others and borders directly on the four water-filled cells. The transverse walls of this cell are cuticularized except in certain small areas. The water contained in the four cells adjacent above is drawn through these areas into the cell by osmotic action due to the presence of sugar in the cell sap.

The water is passed on through the series of stalk cells, whose cross walls have uncuticularized areas, till the mesophyll is reached. This continues till the water in the capillary spaces outside is exhausted, or until the plant is supplied. The water remaining in the four central shield cells is not available to the plant, as the tension of the scale overbalances the absorptive power due to osmosis. This water must pass off by evaporation from the surface of the scale. It will be seen that the scale acts like a suction pump in drawing water into the cells, whence it may be absorbed into the plant by the usual process of osmosis.—F. H. BILLINGS.

ITEMS OF TAXONOMIC INTEREST are as follows: H. and P. SYDOW (Ann. Mycol. **2**:162–174. 1904), among descriptions of many new species of fungi, establish *Microcyclus*, *Phaeodothis*, and *Maurodothis* as new genera of Dothideaceae.—E. L. GREENE (Ottawa Nat. **18**:37–39. 1904) in a second paper on Canadian Antennarias describes five new species.—T. S. BRANDEGEE (Zoe **5**:179–182. 1904) has described new Mexican species of Thelypodium (2), Spermacoce, Gentiana, Gilia, Castilleia, and Krynitzkia.—J. M. GREENMAN (*ibid.* 183–187) has described new species of Cerastium (3), Arenaria, Dalea, Nama, and Eupatorium (2) from Mexico.—KATHARINE BRANDEGEE (*ibid.* 189–194), among other critical notes on Cactaceae, has described new species of Cereus (4) and Mammillaria (2).—L. DIELS and E. PRITZEL (Engler's Bot. Jahrb. **35**:55–160. 1904), under the title "Fragmenta Phytographiae Australiae occidentalis," present

a list of the plants through Proteaceae, with critical notes, including descriptions of new species and the following new genera: *Dielsia* Gilg (Restionaceae) and *Hydatella* Diels (Centrolepidaceae).—KENNETH K. MACKENZIE (Torreya **4**:56–57. 1904) has described a new species of Œnothera from West Virginia.—D. R. SUMSTINE (*ibid.* 59) has described a new species of Hydnum from Pennsylvania.—CHARLES H. PECK (Bull. Torr. Bot. Club **31**:177–182. 1904) has published 16 new species of fleshy fungi.—A .W. EVANS (*ibid.* 183–226. *pls. 8–12.* 1904), in his fourth paper on the Hepaticae of Puerto Rico, has described *Cyclolejeunea* as a new genus containing four species.—H. CHRIST (Bull. Herb. Boiss. II. **4**:393–400. *pl. 1.* 1904) has described a new genus (*Loxsomopsis*) of Filicales (Loxsomaceae) from Costa Rica.—G. LINDAU (*ibid.* 401–418), in his third and closing paper on American Acanthaceae, has described *Juruasia* as a new genus.—K. GIESENHAGEN (Ber. Deutsch. Bot. Gesells. **22**:191–196. *pl. 13.* 1904) has described a new genus (*Sorica*) of Ascomycetes found attacking the sori of ferns.—F. HEYDRICH (*ibid.* 196–199) has described a new genus (*Stereophyllum*) of Corallinaceae. AVEN NELSON (Bull. Torr. Bot. Club **31**: 239–247. 1904) has separated a new genus (*Chondrophylla*) from Gentiana and described new species in Eriogonum (2), Linum, Anogra, Pachylophus, Lavauxia, Gentiana, Hedeoma, Castilleja, and Symphoricarpos.—N. L. BRITTON (Torreya **4**: 93. 1904) has described a new Scirpus from Colorado.—FR. BUBÁK (Hedwigia **43**: 195–196. 1904) has described a new genus (*Lentodiopsis*) of Agaricaceae from Bohemia.—W. R. MAXON (Proc. U. S. Nat. Mus. **27**: 741–744. 1904) has described two new species of Polypodium from Jamaica.—E. ROSENSTOCK (Hedwigia **43**: 210–238. 1904) has begun a series of papers on the pteridophytes of southern Brazil.—P. HENNINGS (*idem* 242–273. *pl. 4*), in his second paper on Ule's collection of fungi from the Amazon region, has described *Hypoxylonopsis* (Dothideaceae), *Parmulariella* and *Uleopeltis* (Hysteriaceae), and *Rehmiomyces* (Bulgariaceae) as new genera.—F. VON HÖHNEL (*idem* 295–299) has described a new genus (*Atractina*) of Hyphomycetes.—W. A. MURRILL (Bull. Torr. Bot. Club **31**: 325–348. 1904), in his seventh paper on the Polyporaceae of North America, presents Hexagona (17 spp., 8 new), Grifola (6 spp., 1 new), *Romellia* (new genus), Coltricia (6 spp., 1 new), and *Coltriciella* (new genus)—O. F. COOK (*idem* 349–355), in a discussion of the nomenclature of the royal palms, has described a new genus (*Plectis*) from Guatemala.—G. E. OSTERHOUT (*idem* 357–358) has described new species of Arabis and Aulospermum from Colorado.—H. SYDOW (Ann. Mycol. **2**: 244. 1904) has described a new genus (*Rickiella*) of Ascomycetes.—F. VON HÖHNEL (*idem* 273–275) has described the new genera *Kordyanella* (Hymenomycetes) and *Debaryella* (Hypocreaceae).—THEO. HOLM (Am. Jour. Sci. IV. **18**: 12–22. 1904), in a report upon a collection of Canadian (British Columbia) Cyperaceae, has described a new Scirpus.—J. M. C.

NEWS.

DURING THE RECENT MEETING of the British Association at Cambridge, the university conferred its doctorate of science on Professor ADOLF ENGLER and Sir W. T. THISELTON-DYER.

PROFESSOR JULIUS WIESNER and DR. LEOPOLD PORTHEIM, of Vienna, recently visited the University of Chicago on their way to the Yellowstone National Park; the former to study the light relations of plants, the latter the algae of the hot waters.

THE DAILY PAPERS announce the death of Dr. RUDOLPH A. PHILIPPI, the eminent German botanist, who has for more than half a century devoted his energies to the development of scientific work in Chile, especially in connection with the museum at Santiago.

M. A. CHRYSLER, of the University of Toronto, and later Fellow in the University of Chicago, has been appointed senior assistant in the Department of Botany of Harvard University. For the past summer he has been conducting ecological field-work for the Maryland Biological Survey.

THE PRELIMINARY program of the eighth international geographic congress, which convened in Washington, September 7–10, contained an announcement of a section for biogeography. In addition to papers by American plant geographers, announcement was made of papers by Professor FLAHAULT, of Montpellier, Dr. DRUDE, of Dresden, and M. CHRISTEN, of Bern.

AT THE SUMMER CONVOCATION (September 2) of the University of Chicago the degree of Ph.D. was conferred upon three candidates in botany. The names of the recipients and the subjects of the theses are as follows: W. J. G. LAND, "A morphological study of Thuja;" W. B. MCCALLUM, "Regeneration and polarity in plants;" R. B. WYLIE, "The morphology of *Elodea canadensis*."

THE INSTALLATION of Lanston monotype machines in the University Press has enabled the publishers to make notable improvements in the typography of the current volume of the BOTANICAL GAZETTE, to which we direct the attention of our subscribers. It will also be noticed that as the cost of composition has been thus reduced, the prices quoted for separates are 20 per cent. lower than formerly.

PROFESSOR N. L. BRITTON and DR. J. N. ROSE, having completed their monograph of the North American Crassulaceae, have undertaken a study of the Cactaceae. Dr. ROSE will spend considerable time in field work, especially in central and southern Mexico, where the Cacti are in inextricable confusion. There will be brought together first in New York and Washington large collec-

tions of living plants from which the descriptions will be drawn. Living material is desired from all parts of the southwest, and the National Museum will gladly furnish means for sending material to Washington.

DURING HIS VISIT to the United States, Professor HUGO DEVRIES has delivered courses of lectures at the University of California and at the University of Chicago. These lectures are to be published at once, and will bring to American readers a compact and clear exposition of the mutation theory and the experiments upon which it is based. At the University of Chicago, on September 2, Professor DEVRIES delivered the convocation address, his subject being "Evidence of evolution," and also received the honorary degree of LL.D. He is also to take part in the International Congress of Arts and Sciences at St. Louis, September 19–25.

THE PRIVATE HERBARIUM of Dr. JOHN K. SMALL consisting of 21,900 sheets, fully representing his collections in the southern United States, has lately been acquired by the Field Columbian Museum. The herbarium also contains several good series by other collectors. notably ROBERT BROWN'S Australian plants; GARBER'S Florida plants; HELLER'S Virginia, North Carolina, and Pennsylvania plants; KEARNEY'S Kentucky and Tennessee plants; LEWTON-BERG, and REYNOLD'S Florida plants; ORCUTT'S Lower California plants; PORTER'S Pennsylvania plants; SMALL and HELLER'S Pennsylvania, Tennessee, North Carolina, and Virginia plants; and WILKINSON'S Mexican plants.